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Characterizing Late Pleistocene and Holocene Stone Artefact Assemblages from Puritjarra Rock Shelter: A Long Sequence from the Australian Desert

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ABSTRACT. This paper presents the first detailed study of a large assemblage of late Pleistocene artefacts from the central desert. Analysis of the lithics shows show that Puritjarra rock shelter was used more intensively over time, with significant shifts in the character of occupation at 18,000, 7,500 and 800 B.P., reflecting significant re-organization of activities across the landscape. The same generalized flake and core technology appears to have been used for over 30 millennia with only limited change in artefact typology over this period.

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Excavations at Puritjarra rock shelter provide a rare opportunity to examine an assemblage of late Pleistocene artefacts from central Australia, dating as early as c. 32,000 B.P. This study presents a quantitative analysis of the flaked stone artefacts at Puritjarra, comparing the Pleistocene and Holocene assemblages at this site. It is also the first detailed study of an excavated assemblage of lithics in the Australian arid zone since research by R.A. Gould on the Holocene artefact assemblages at Puntutjarpa (Gould, 1977) and Intirtekwerle (James Range East) (Gould, 1978), and R.J. Lampert at Hawker Lagoon (Lampert & Hughes, 1988). However, it differs from these earlier studies in making the history of site use a focus of analysis, rather than stone tool systematics.

This approach reflects current trends in lithic research. Over the last thirty years, interpretation of flaked stone artefact assemblages in Australia has swung from stone tool systematics to a more systemic perspective on stone artefacts (Holdaway & Stern, 2004—see also Cundy, 1990; Hiscock & Allen, 2000; Hiscock & Attenbrow, 2003; Holdaway, 2004). Ethno-archaeological studies involving the last generation of Aboriginal people to rely on stone artefacts have been very influential in this shift in perspective (Cane, 1984, 1992; Gould, 1968; Gould *et al.*, 1971; Hayden, 1977, 1979; O'Connell, 1977). But Australian research also reflects the impact of international trends in lithic analysis, stimulated by the work of L.R. Binford on site use, mobility patterning and organizational variability amongst foraging peoples (Binford, 1982). Recent research in the Australian arid zone emphasizes the effects of residential mobility, access to stone, the flaking properties of different raw materials, and changes in intensity of occupation as key factors in structuring the archaeological record (Barton, 2003; Veth, 1993).

Research problems in central Australia

The need for an extended application of this approach, to excavated assemblages of flaked stone artefacts from the western and central desert, has grown steadily since the prehistory of these regions was mapped out in a series of regional studies in the 1980s and 1990s (Smith, 1988; Thorley, 1998b; Veth, 1989a). Some site use issues that now warrant more detailed analysis of flaked stone assemblages include:

The nature of late Pleistocene occupation. Late Pleistocene groups in the Western Desert and central Australia appear to have been small, highly mobile groups using wider territories than those in the Holocene (O'Connor *et al*., 1998: 21; Smith, 1989, Smith *et al*., 1998; Thorley, 1998b: 316). Preliminary analysis of changes in residential mobility, using a range of archaeological indices (including extent of stone reduction and artefact diversity), at the three known late Pleistocene sites in the region—Kulpi Mara, Puritjarra and Serpent's Glen—supports this proposition (Veth, 2005a) but detailed analysis of flaked stone assemblages is required to test it.

Impact of the last glacial maximum. Increasing aridity around 18,000–20,000 B.P. is thought to have led to changes in residential mobility, territory and regional networks (Smith, 1989, Smith *et al*., 1998; Veth, 1989b, 1993, 2005b). Both Kulpi Mara and Serpent's Glen were abandoned after about 23,000 B.P. Only Puritjarra, near reliable water, shows evidence for use between 23,000 and 13,000 B.P., raising questions about the pattern of occupation at this time. Both Smith (1989) and Thorley (1998a: 43) argue that Puritjarra should show evidence of more intensive "water-tethered" occupation, with Smith opting for a "point-to-point" rather than a "home range" pattern of mobility (Smith, 1989).

Holocene shifts in mobility patterns. Thorley (1998b, 1999) shows there was widespread occupation of the upper reaches of the Palmer River catchment at 3,000–4,000 B.P., suggesting increased residential mobility and greater use of ephemeral waters. Hiscock (1994) suggests that the appearance of new toolkits around 4,000 B.P. represents a technological response to increased mobility, driven in part by greater environmental variability associated with ENSO. Although data on the mid-Holocene (4,000–6,000 B.P.) is comparatively poor for the western and central desert, analysis of excavated assemblages from Puritjarra and Serpent's Glen can test whether there are significant changes in site use at this time.

Late Holocene intensification. The last millennium appears to have been a period of major change in the Western Desert and central Australia (Smith, 1996; Thorley, 1999; Veth, 1993, 2005b), possibly involving shifts towards higher regional populations. There are indications of more intensive occupation and significant increases in the level of site use after 1,500–1,000 B.P.—especially in the lower reaches of catchments, in sites on sand plain and valley floors (Smith, 1988, 1996; Thorley, 1998b: chapter 8). The most pressing need is to "unpack" this phase of occupation and determine whether it reflects changes in the duration of visits (more sedentary occupation), changes in group size, or changes in the frequency of visits (more frequent cycling of groups through these sites). Both Behr (1990) and Law (2003) have suggested that increased mobility is involved in these changes, although both studies were limited (Behr looked mainly at cores; Law focussed only on retouched flakes).

Aim of this study

My aim is to provide a quantitative analysis of the flaked stone artefacts from Puritjarra in sufficient detail to characterize lithic assemblages from different phases of occupation of the shelter. This will provide the basis for reconstructing the history of use of the shelter and its place within a changing cultural landscape—and for testing ideas about mobility, site territory, and site use outlined above. There are limits to what can be inferred from a single site. However, this analysis of the Puritjarra assemblages should provide the basis for comparison with Kulpi Mara and Serpent's Glen, when quantitative data on their flaked stone assemblages becomes available.

This study is not primarily a technological or typological study but rather history-in-a-locale—or as L.R. Binford termed it an "archaeology of place" (Binford, 1982). It provides a historical portrait of a key desert site, complementing other studies which deal with the ^{14}C and luminescence chronology of the site (Smith *et al*., 1997; Smith *et al*., 2001), as well as its environmental evidence and sedimentary history (Bowdery, 1995, 1998; Smith *et al*., 1995), flaked stone artefacts (Behr, 1990; Law, 2003), grindstones and plant use (Smith, 2004), rock-art (Rosenfeld & Smith, 2002; Ross, 2003), ochres (Smith *et al*., 1998), and Aboriginal history of the rock shelter (Smith, 2005a).

Background

Environmental setting. The western part of central Australia contains a diversity of country, including sand plain, dune fields, stony desert, salt lakes and rock outcrops. Scattered across the dominant sand hill and spinifex country, is an archipelago of small rocky ranges, often only a few kilometres long, and visible one from another on the horizon. Puritjarra is situated in the Cleland Hills (23°50'S 130°51'E), one of these small range systems, 60 km west of the MacDonnell Ranges (Fig. 1). The area is a transitional zone between ranges and desert lowlands: it shares the ecological and biogeographical features of country further west but is within a few days walk of the main central Australian range system.

Palaeoenvironments. Direct palaeoenvironmental evidence for the region is sparse (but see Bowdery, 1995, 1998; Hesse *et al*., 2004, 2005; Smith *et al*., 1995). Available data suggests an open local vegetation during much of the late Pleistocene, with scattered trees and sand hill shrubs but little grass cover—especially during the peak of the last glacial maximum around 18,000 B.P. Phytolith data and charcoals from the Puritjarra sediments indicate that the post-glacial period in central Australia saw a rapid amelioration of arid conditions with an increase in grasses and acacias by 13,000 B.P. The early Holocene vegetation may have been a mosaic of acacia woodland and spinifex communities, reflecting better rainfall at this time. Megirian *et al*. (2002) report that the early Holocene fauna included a wide range of macropods, as well as hairy-nosed wombat (*Lasiorhinus* cf. *latifrons*) and Tasmanian Devil (*Sarcophilus harrisii*), both of which became regionally extinct in the mid-Holocene. The mid-Holocene saw a decline in grass levels after 5,000 B.P., possibly in response to increasing aridity, which only recovered again after about 1,500 B.P. as the modern vegetation took shape. Assuming that periods

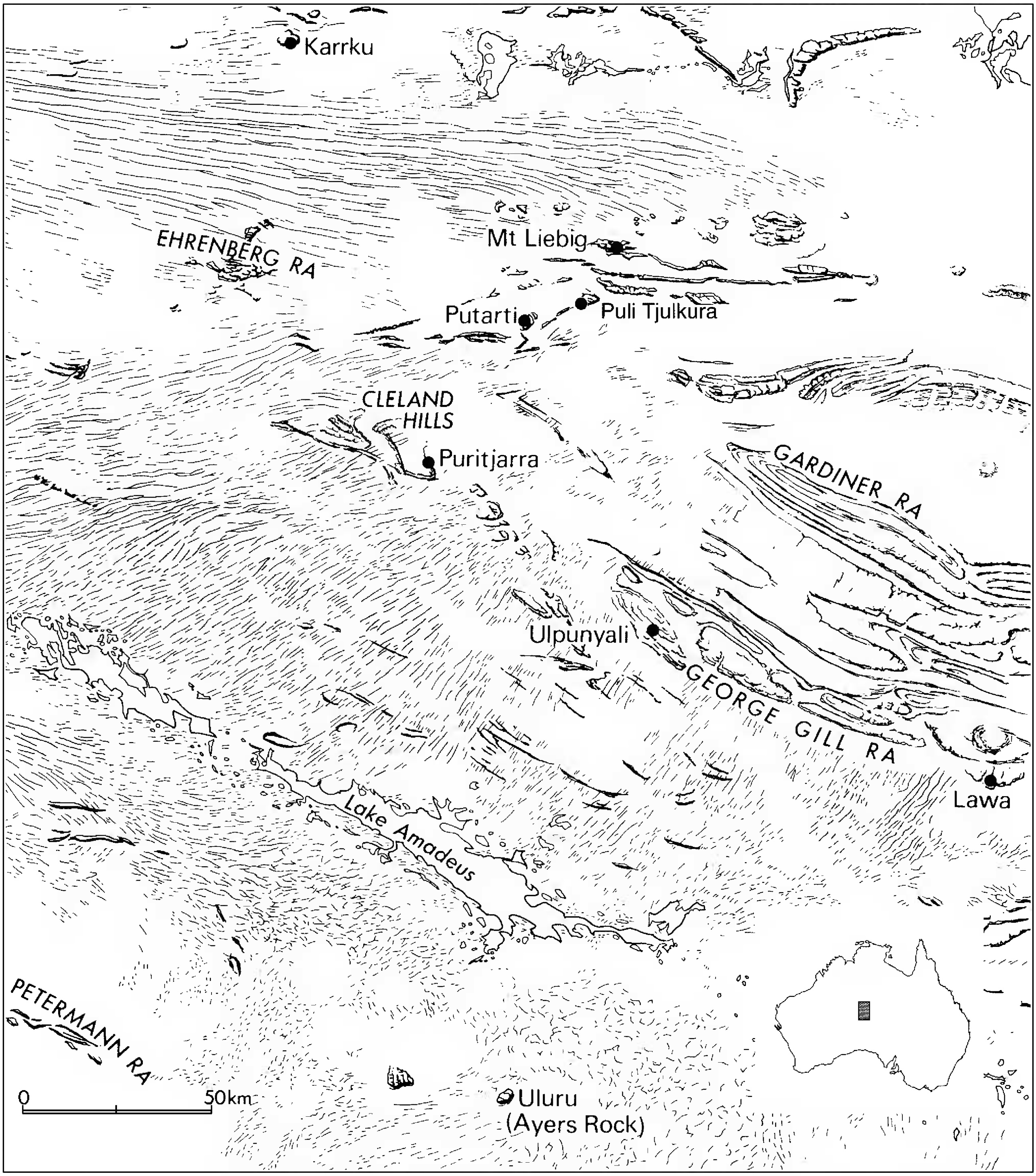


Fig. 1. The western part of central Australia showing the location of Puritjarra rock shelter and regional topography of longitudinal dunes, sandstone ridges and salt lakes.

of high representation of Poaceae in the phytolith record reflect better summer rainfall (which is likely), the last millennium was the most favourable period for human settlement in Central Australia during the last 50,000 years (Bowdery, 1995: fig. 6.1).

Puritjarra rock shelter

The rock shelter is situated at the foot of a small (15 m high) sandstone escarpment and faces out onto sand plain and dune field supporting spinifex hummock grassland and low shrubs. Behind and above the shelter there is an extensive low sandstone plateau with an open shrub cover of cypress pine (*Callitris glaucophylla*) and hill mulga (*Acacia macdonnelliensis*). There is a small ephemeral rock hole adjacent to the site. Reliable water is available at Murantji rock hole, a large semi-permanent (possibly spring-fed) rock hole c. 2 km north of the rock shelter. Morphologically, the site is a large open rock shelter formed in Ordovician-Devonian Mereenie sandstone, with a level sandy floor of c. 400 m^2 (Fig. 2). Floor to ceiling height is c. 12 m across much of the site.

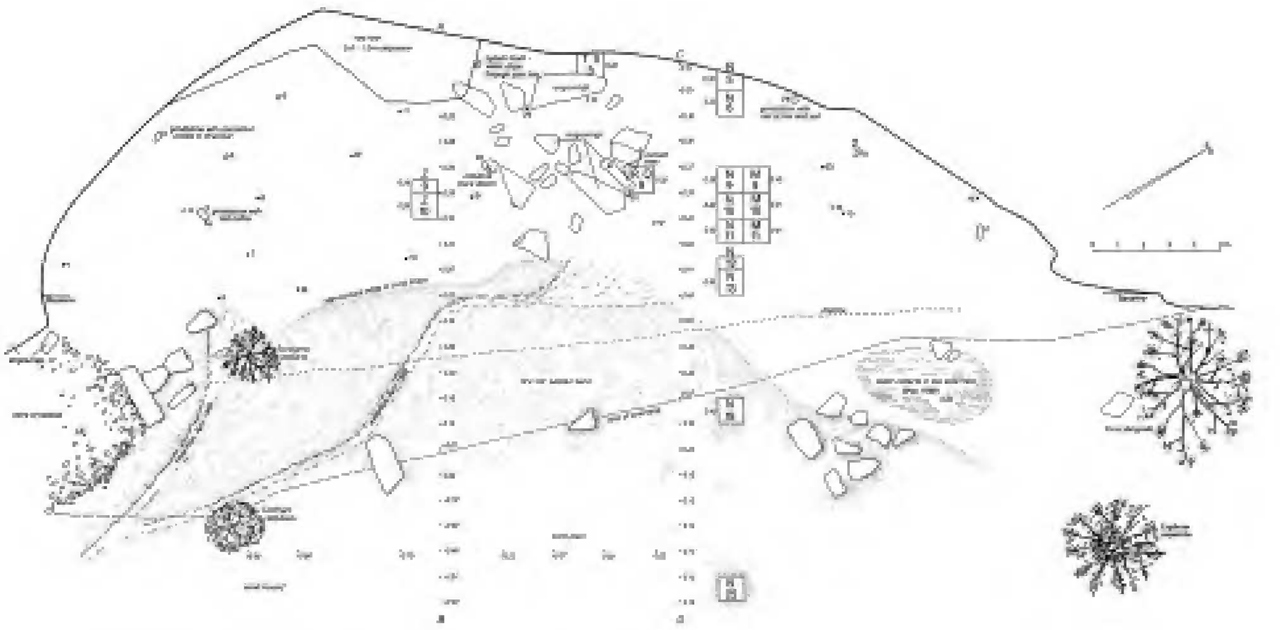


Fig. 2. Plan of Puritjarra rock shelter showing layout of excavation trenches. Also shown are spot heights (m below datum) for the ground surface.

Rock art. The rock art is described elsewhere by Rosenfeld & Smith (2002) and Ross (2003). A small number of rock engravings, mainly plain pecked circles, and incised lines occur on boulders embedded in the floor of the shelter (Fig. 2). Radiocarbon dates for the sedimentary surface these rest on, together with estimates of the age of the patina covering the engravings, suggest the pecked circles date between 13,500 and 7,500 B.P. (Rosenfeld & Smith, 2002:117). The rear wall of the rock shelter also forms a large painted frieze, 2 m high and c. 40 m long, containing more than 400 individual paintings, prints or stencils, most of which appear to have been produced during the last millennium.

Excavations 1986–1990

Three seasons of archaeological excavations were undertaken at the site between 1986 and 1990. The excavations, which are large by contemporary Australian standards, were intended to sample the shelter floor and stratigraphy across the site, and to explore the changing spatial structure of occupation within the rock shelter (Fig. 2). Given the paucity of knowledge about late Pleistocene and early Holocene occupation in the arid zone, I also aimed to recover an assemblage of artefacts large enough to support a quantitative analysis. Excavation trenches were positioned to sample the major discard zones across the rock shelter, particularly areas where larger artefacts such as cores and grindstones might accumulate. The Main Trench was opened up in the northern sector of the site to allow access to the lower part of the stratigraphic column, where rock fall had blocked more limited trenching in 1986 (Smith, 1987), and to follow a discrete layer of artefacts and occupation debris (unit 2c below) that emerged during the 1988 field season.

Excavation units (spits) take into account sedimentary bedding, natural stratigraphy and occupation features (such as pits and hearths) and therefore vary from 20–100 mm in depth (20–30 mm for most spits in layer II) and up to 1 m^2 in plan. During excavation of the Main Trench in 1988 and 1990 (involving grid-squares N11–N13, M10–M11) an attempt was made to record all artefacts in layer II in-situ. The aim was establish whether excavating in 20–30 mm spits was obscuring finer pulses of occupation (The results show this was not the case—see Fig. 21). These "levelled" finds form 67% (N = 237) of the total artefacts recovered from these spits.

Individual spits and small finds are identified using a hierarchical system, which describes their provenance (following Johnson, 1979:154–155). For instance, M10/1-7 is: (grid square M10)/(spit 1)-(find number 7). Both spits and finds are numbered in sequence within individual grid squares. Following Johnson (1979), there is no direct correlation between co-numbered spits in different grid squares.

Chronology

The chronology for the site is provided by a series of 31 radiocarbon dates on charcoal (Smith *et al*., 1997; Smith *et al*. 2001). Nine luminescence dates on sediments are also available for the site. Some radiocarbon anomalies noted in the 1997 study have been shown to be due to younger contaminants rather than displacement of charcoal (Smith *et al*., 2001). Extensive work on the chronology of the site since the preliminary reports (Smith, 1987, 1989) shows that levels initially dated to 22,000 B.P. are much older: c. 32,000 B.P. (^{14}C) or 35,000 years ago (TL). Together with phytolith research by D. Bowdery (1995, 1998), this work more accurately identifies the level corresponding to the peak of the last glacial maximum at this site (at 105 cm below datum), and also provides a better age estimate for the base of unit 2a (see below).

Using the radiocarbon chronology the occupational history of the rock shelter can be briefly summarized as follows: the site was occupied by at least c. 32,000 B.P. and use of the shelter continued throughout the late Pleistocene; the level of occupation increased after c. 7,500 B.P., and again during the last millennium.

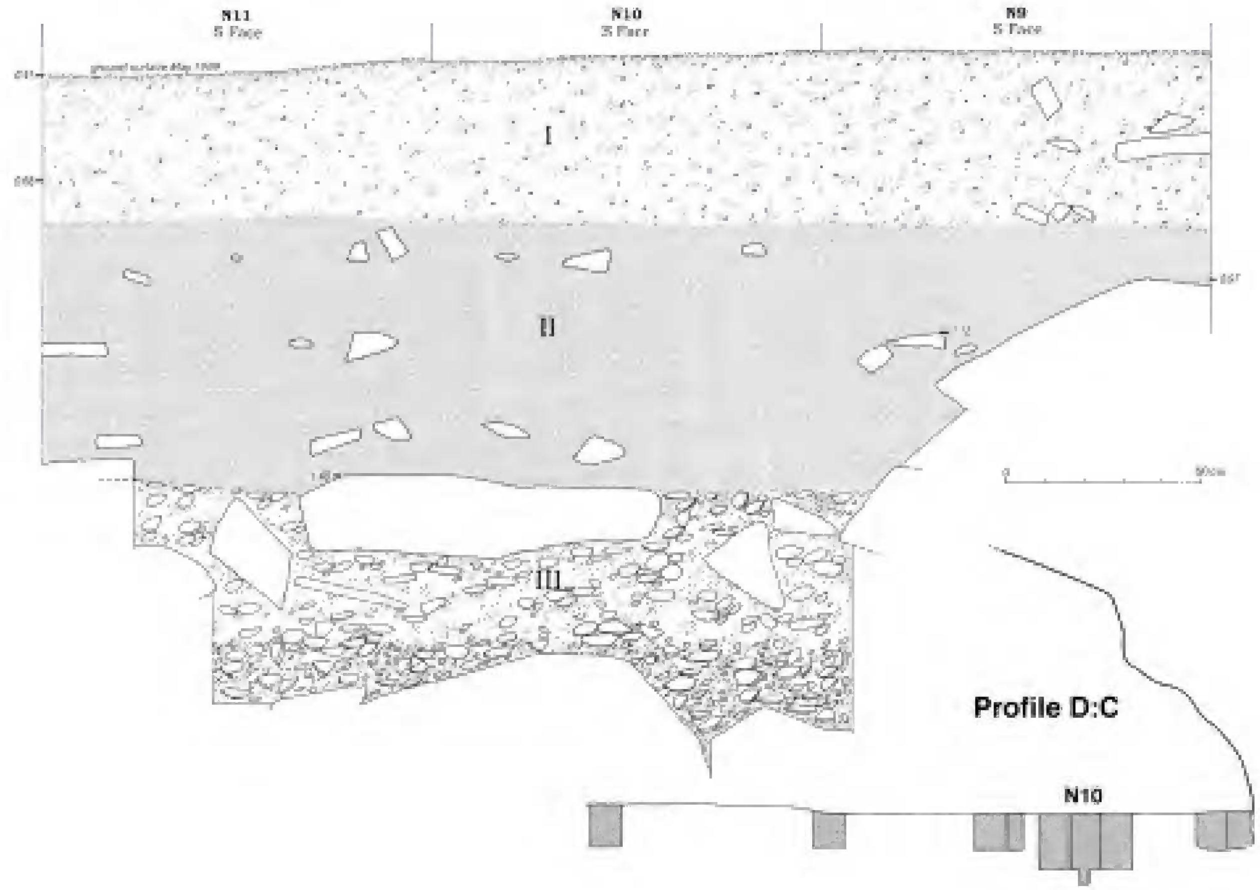


Fig. 3. Stratigraphic section, south face of the Main Trench, showing horizontal bedding of layers I–III. The inset provides a sagittal profile across the rock shelter.

Layers

The deposit, which is 2 m deep, is divisible into three major lithostratigraphic units (layers I to III) (Figs 3 and 4). These are more or less horizontally bedded and are made up of fine aeolian sediments, originating outside the shelter, together with varying size-grades of sandstone fragments derived from the shelter itself.

Layer III, consisting of rounded sandstone rubble, fine dark red sand, and large roof fall debris, is the oldest of these layers. It is at least 1.20 m thick but its full depth was not established. Luminescence dating (Smith *et al.*, 1997) indicates that the upper part of the layer dates to 96±7 ka (AdTL91011), suggesting a last interglacial age for much of the layer.

Layer II is a distinctive layer of hard, compacted, red silty sediment, about 60 cm thick. It rests unconformably on layer III. Both ^{14}C and luminescence dating techniques indicate the greater part of layer II is late Pleistocene in age, ranging in age from about 7,500 B.P. to 9,000 B.P. for the top of the layer to 44.8±3.6 ka (AdTL91010) at its base.

Layer I, which is about 42 cm thick, is a consolidated layer of fine, brown aeolian sand and rock spall, spanning the last 7,500 years. Its accumulation may represent more aggressive weathering of the roof of the shelter, initiated under the more humid conditions of the early Holocene.

Evidence for human occupation of the rock shelter is restricted to layers I and II. Apparent rates of sediment deposition at Puritjarra are low, averaging 23 mm per 1,000 yr (using the ^{14}C chronology), but are not unusual for Australian rock shelter deposits. Because of the increasing compaction with depth of sediments, these figures are likely to underestimate actual rates of sediment accumulation, especially for layer II.

The first people to visit Puritjarra would have found a rock shelter of similar size and morphology to that of the present day. The roof-fall debris in layer III represents the last major event to significantly alter the morphology of the rock shelter. Excavations in grid-square N18 revealed a column of rocks directly beneath the leading edge of the overhang, showing there has been little retreat of the shelter over the last 10,000 years. However, the available floor area appears to have changed over time. Initially the only large rock-free floor area was in the northern half of the shelter. As layer II built up it buried much of the rock fall and rubble in other parts of the shelter, extending the area available as a living surface.

Analytical units

Stratigraphic correlations between trenches are summarized in Fig. 4. The deposit can be divided into seven analytical units (units 1a–c within layer I, units 2a–d within layer II). Each represents an identifiable occupation horizon—which can be traced across the site—or parts of the deposit intercalated between these horizons. As these are divisions based on cultural stratigraphy, not arbitrary units, they do not necessarily represent equivalent blocks of time. Essentially, the analytical units represent the finest scale

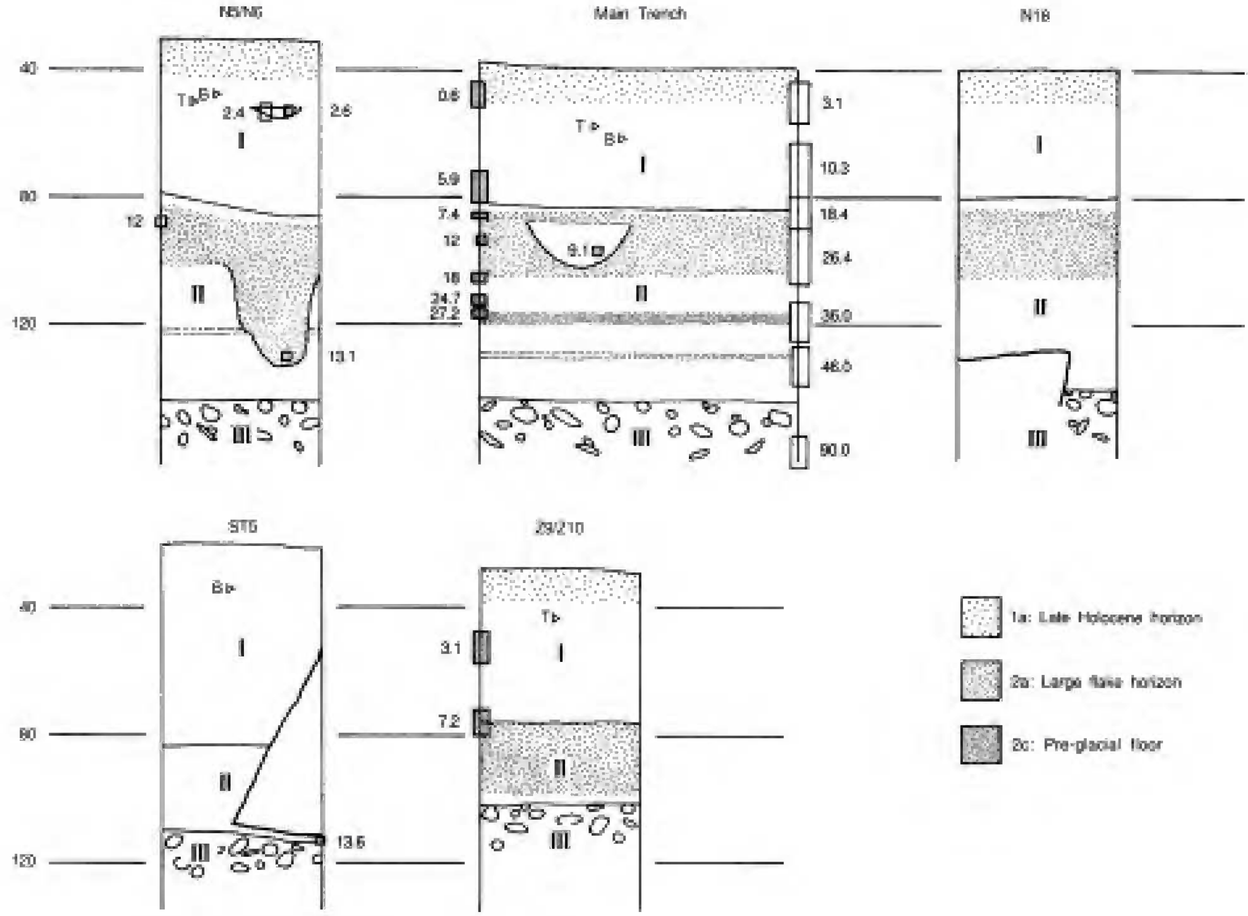


Fig. 4. Schematic diagram showing stratigraphic correlations between trenches. Layers I–III are labelled in bold. Identifiable cultural horizons (units 1a, 2a and 2c) are shown (stippled), as well as dated hearths (plano-convex features), ^{14}C determinations (hatched rectangles), luminescence dates (open rectangles) and the maximum depth of late Holocene artefacts in each trench (T tula adzes; B backed artefacts/geometric microliths). Grid lines show depth (cm) below site datum. Horizontal stippled lines at 120 cm depth in N5/N6 and in the Main Trench show the position of a silty band identified in grain-size analyses.

Table 1. Correlation of layers, analytical units and cultural horizons.

layer	unit	estimated age years B.P.	cultural horizon	indicative depth* (cm) below datum	indicative depth* (cm) below surface	related features
I	1a	0–800	Late Holocene zone of intensive occupation	40–50	0–10	*Hearths and ash lenses*: N5/2-1, N6/3-1, N6/4-1, N10/2, N11/3-4, M10/3-1, M9/2-1, M9/2-2, Z9/2, Z9/3. *Pits*: N12/3, N12/2-1, N25
I	1b	800–3,500		50–70	10–30	*Hearths and ash lenses*: N5/5-3, N6/7-2
I	1c	3,500–7,500		70–85	30–45	*Hearths*: N9/6-2. *Pits*: N11/12, N12/8-3
II	2a	7,500–18,000	Zone of large flake implements	85–105	45–65	*Hearths*: N5/15-13, M10/21. *Pits*: N5/25
II	2b	18,000–32,000		105–116	65–76	
II	2c	32,000	Discrete band of lithics and occupation debris	116–120	76–80	
II	2d	>32,000		120–145	80–105	

* These are indicative depths for the Main Trench. The thickness and the elevation of the layers and horizons vary across the rock shelter.

that can be used to integrate material from different trenches. They also provide an independent crosscheck of my interpretations of lithostratigraphy and chronology (^{14}C and TL). Figure 4 shows that all three lines of evidence (lithostratigraphy, cultural stratigraphy and chronostratigraphy) essentially knit the site together in the same way.

These analytical units allow a spatial component to be incorporated into various analyses. With such an approach, there is always a risk that fine-grained temporal trends will be obscured, creating a false impression of sharp strophic change—as Frankel (1988) cautions. An alternative approach is to analyse a stratigraphic column from a single grid square. The main limitations of the latter are smaller sample sizes and the difficulty of integrating results from different grid squares or trenches. (Note: as layers vary in thickness and absolute height across the site, generalized age-depth data are a poor guide to grouping spits for analysis). In this study, I have routinely crosschecked one type of analysis against the other

Table 2. Grouping of excavation units by analytical unit.

grid square	1a	1b	1c	2a	2b	2c	2d
	analytical unit						
M9	1–2	—	—	—	—	—	—
M10	1–4	5–10	11–14	15–22	23–25	26	27–28
M11	1–4	5–9	10–14	15–23	24–26	27–28	29–33
N5	1–4	5–8	9–14	15–25[h]	—[j]	—[j]	27
N6	1–3	4–8	9–17	18–20	—	—	—
N9	1–3	4–5	6	7–9	10–11	—[k]	12
N10	1–3	4–5	6[g]	8–10	11	—[k]	12–13
N11	1–4	5–10	11–16	17–26	27–29	30–31	32–35
N12	1–4	5–6	7–8	9–20	21–25	25–27[l]	28–35
N13	1–4	5–10	11–13	14–19	20–22	23–24[m]	25–28
N18	1–2	—[f]	—[f,g]	8–12	13–17	18	19–22
QR9	1–2	3–4	5[g]	7–9	—	—	—
ST5	1–2[e]	—[f]	—[f]	—[i]	—	—	—
Z9	1–6	—[f]	—[f]	26–38	39	—	—
Z10	1–2	—[f]	—[f]	6–8	9–10	—	—

[e] The top 10 cm of the profile is arbitrarily taken to represent 1a because overall artefact densities are too low to delineate the lower boundary of the unit.
[f] There is insufficient data here to distinguish between units 1b and 1c. N18/3-N18/6, ST5/3-ST5/7, Z9/7-Z9/25 and Z10/3-Z10.5 are therefore "unassigned layer I".
[g] Spits which straddle the interface of layers I and II (N10/7, N18/7, QR9/6) are "unassigned layer II".
[h] N5/25 is a pit containing material derived from the level of N5/19. Therefore units N5/19-25 are combined for most analyses.
[i] The concentration of coarse debitage and other large items against the wall of the shelter in ST5 make it difficult to isolate the changes in mean artefact size that characterize 2a. ST5/8-ST5/10 are therefore "unassigned layer II".
[j] N5/26 is "unassigned layer II" as it is from an area disturbed by the N5/25 pit.
[k] The 32,000 B.P. surface was not recognized during the initial excavations in 1986. The recording methods used in N9 and N10 do not allow artefacts to be securely assigned to unit 2c.
[l] Material from N12/25 is excluded except for individually levelled-in artefacts with depths of 116 cm below datum.
[m] Material in N13/25 is stratified immediately beneath the floor, and can be grouped with 2c for some analyses.

Table 3. Overall composition of the flaked stone assemblage. Data are numbers of artefacts (6 mm sieve fraction) in each category.

analytical unit	retouched artefacts	unmodified flakes flakes	cores	debitage	total number number
1a	319	996	34	5878	7227
1b	153	531	14	3096	3794
1c	59	317	11	1269	1656
unassigned layer I[e]	66	425	28	1809	2328
2a	81	430	39	1046	1596
2b	4	76	2	157	239
2c	2	11	—	29	42
2d[f]	—	9	1	12	22
unassigned layer II[g]	3	34	2	126	165
total number	687	2829	131	13422	17069

[e] 1b and 1c cannot be separated in some trenches (N18, ST5, Z9/Z10).
[f] One core and 5 flakes are doubtful artefacts and excluded from further analysis (see text).
[g] Mainly artefacts from the interface of layers I and II in N10, N18, ST5 and QR9 where the upper limit of 2a is poorly defined.

(see Figs 14 and 20), testing any differences between analytical units (with their larger sample size and spatial perspective) against trends in individual stratigraphic columns (with limited sample size but finer-grained temporal data).

Table 1 shows the relationship between layers, identifiable cultural horizons and analytical units. Table 2 summarizes the grouping of excavation units (spits) into analytical units. Each of the analytical units is described below.

Unit 1a: Late Holocene horizon (0–800 B.P.). The greatest concentrations of chipped stone artefacts, grindstones, ochre, charcoal, bone and eggshell occur in the upper 5–10 cm of the deposit across the site reflecting a substantial increase in the level of use of the rock shelter from about 800 B.P. As well as a dense horizon of occupation debris, this phase of use left a series of hearths, pits and ash lenses across the site.

Unit 1b: (**800–3,500** B.P.). With one exception, geometric microliths and tula adze slugs are restricted to units 1a and 1b in the upper 25–30 cm of the deposit. Their stratigraphic distribution is used to divide the deposit beneath unit 1a into a horizon containing microliths and adzes (unit 1b) and an underlying horizon, pre-dating the major use of small-tool phase artefacts at this site (unit 1c). In trenches where there are too few geometric microliths and tula adze slugs to make this assessment (N18, ST5, Z9/Z10), the deposit beneath unit 1a is simply listed as "unassigned layer I" (Table 3). Law (2003:118–126) suggested the base of unit 1b may be as old as 6,000 B.P. but based his argument on selective use of the ^{14}C date series. In fact, the base of unit 1b is bracketed by ANU 6602 (2,640±70 B.P.—unit 1b) and Beta 18882 (5,860±150 B.P.—unit 1c).

Unit 1c: (**3,500–7,500** B.P.). Material from the lower part of layer I is grouped together as unit 1c.

Unit 2a: large flake implement horizon (**7,500–18,000** B.P.). Large flake implements >50 g and steep-edged scrapers occur in the upper part of layer II. During excavation, the greatest concentration of these implements appeared to be between 95–98 cm below datum, but subsequent tabulation of finds shows that this is just the central part of a broader horizon of large flake tools at depths between 85 cm and 105 cm below datum. In stratigraphic terms the horizon occupies a band 20 cm thick within the top of layer II. Its central part is well dated between 10,500 B.P. and 12,000–13,000 B.P. and the horizon must span the time period from about 7,500 B.P. to c. 18,000 B.P. (Note: an earlier study by Smith *et al*. (1998) used a preliminary age estimate of c. 13,000 B.P. for the base of 2a. The implications of this are discussed below in "History of the rock shelter"). Several features are associated with this horizon—the N5/25 pit and M10/21 hearth—and some, if not all, of the petroglyphs at the site.

Unit 2b: (**c. 18,000–32,000** B.P.). Material beneath the large flake horizon, but stratigraphically above the 32,000 B.P. palaeosurface, is grouped as unit 2b. A division into units 2b and 2c is only possible in the Main Trench.

Unit 2c: pre-glacial surface (**c. 32,000** B.P.). This is a thin band c. 2 cm thick of stone artefacts, charcoal and pellets of red ochre extending across N11–N13 and M10–M11 in the central part of rock shelter at depths below datum between 116–120 cm. Judging from the narrow vertical spread, this material was deposited on a palaeosurface of some kind, although this surface could not be defined during excavation or identified in sediment thin-sections. Attempts to refit artefacts from this level were unsuccessful although several artefacts clearly relate to the same knapping event. It is possible that unit 2c represents a palimpsest of material from several visits, perhaps accumulated on the surface over some time, rather than an assemblage of strictly contemporaneous material.

Unit 2d: (**>32,000** B.P.). The excavation uncovered a small number of artefacts stratigraphically lower than the 32,000 B.P. palaeo-surface. These fall into two groups. The first includes red ochre, sandstone, silcrete and chert flakes, and debitage, all from spits immediately beneath the 2c palaeosurface in the Main Trench (16 artefacts in total). This material is unlikely to be much older than 35,000 B.P. The second group consists of five small flakes and a possible core, from the base of Layer II, from widely separated find spots across the site. A small piece of red ochre was also recovered from this level. Whether these lithics are human artefacts or naturally flaked pieces, or artefacts possibly displaced from a higher level, is unclear and they are therefore excluded from the analysis (but see "History of the rock shelter" for description of these finds).

Where the cultural stratigraphy is not well resolved, some analytical units cannot be isolated. In fact, 15% of artefacts are from spits that cannot be securely assigned to one or another of these units (Table 3: "unassigned layer I" or "unassigned layer II"). My aim is to provide optimal separation of diachronic assemblages, based on internal stratigraphic markers, rather than assign all spits to a unit. Therefore, I am critical of Law's analysis of retouched flakes, which arbitrarily re-allocates spits between units 1b and 1c (Law, 2003: 151), potentially obscuring differences between these units.

Materials and methods

Recovery and sorting. During excavation all material was sieved through nested 6 mm and 3 mm sieves and bagged according to excavation unit. Sorting of sieve residues and the separation out of flaked stone artefacts from these residues was carried out in the laboratory. The only exceptions to this routine were artefacts recorded during excavation ("levelled finds"), which were given individual find numbers and bagged separately. The 6 mm fraction was sorted in its entirety and some 17,069 artefacts were recovered (Table 3). However, it was difficult and time consuming to separate the fine chipping debris (flakelets) from the 3 mm sieve fraction. After wet sieving, and the removal of charcoal by flotation and manual sorting, the bulk of this fraction was made up of finely comminuted sandstone gravel, containing up to 300 flakelets per kg. Therefore, separation of fine flaking debris from the 3 mm sieve fraction was undertaken for only selected stratigraphic columns (N5, N10 and M10).

Artefacts from the 6 mm fraction were sorted into several broad classes as follows:

Retouched artefacts. Pieces or flakes with secondary flaking. Fine edge damage (chattering or nibbling) was ignored but artefacts with more marked edge damage or utilization were included. Many of the artefacts are pieces of large implements or small fragments of a retouched edge.

Unmodified flakes (**≥1 cm^2**). Both complete and broken flakes. In the case of broken flakes, only proximal ends, where the striking platform or bulb of percussion could be identified were included. This follows Andrefsky (1998: 88) rather than the more precise calculation of MNF (minimum number of flakes) given in Hiscock (2002: 254), which incorporates counts of distal fragments. At Puritjarra, I was not confident that MNF could be accurately determined given that distal flake fragments on local silicified sandstone were difficult to distinguish from shatter fragments or natural spalls of this material.

An arbitrary lower size limit of 1 cm^2 was used to exclude very small artefacts from this class. Flakes less than 1 cm^2 are unlikely to be systematically recovered in a 6 mm sieve mesh. I have followed procedures advocated by Johnson (1979: 69, 97, 157) who argued that size data should be filtered using a slightly higher size threshold to clean up the data and ensure comparability between excavation units.

Cores. These are pieces serving as a primary source of flakes. Any piece from which at least three flakes (≥10 mm long) have been struck was classified as a core unless there were other grounds for including it as an implement.

Debitage. All remaining artefacts—including shatter fragments, chips, flakes <1 cm^2, distal or medial fragments of flakes, and amorphous flaking debris—were classed as debitage. A distinction was made between debitage from the 6 mm sieve fraction and the fine chippage recovered from the 3 mm sieve. The latter is not included in any counts unless explicitly stated.

Cores and retouched artefacts were further classified according to category or type. Details are given below. Existing typological schemes were used so that the Puritjarra artefacts could be compared with other assemblages, even though it is now clear that some of the forms described are reduction states rather than formal types (cf. Hiscock & Attenbrow, 2003). These typologies also represent a useful starting point for developing a first-order characterization of an assemblage, as they include a range of artefact morphologies which are widely understood and readily re-interpreted from a range of perspectives (either as reduction states of particular implements, debitage from specialized knapping processes, manufacturing blanks, formal or functional implement types).

Sampling the assemblage

Flake attributes. Trends in flake weight over time, or by raw material, or zone within the shelter, were examined using the entire assemblage of flakes (N=2829).

For detailed *attribute* analysis (for attribute definitions see Appendix 1), a sample of 931 flakes was drawn with several factors in mind. First, only flakes for which platform variables could be measured were recorded. Second, in practical terms it was more efficient to use excavation units as the basis for sampling rather than attempt to locate individual flakes within the collection. Once an excavation unit was chosen, all unretouched flakes ≥1 cm^2 were described. Third, the sample had to be drawn in a way that took intra-site spatial variability into account. These constraints were met as follows.

- All flakes from layer II were recorded, giving as large a sample of flakes from 2a–d as possible.
- In layer I, all flakes from N11 and N5 were recorded giving a continuous stratigraphic column at two points within the shelter. The numbers of flakes in N11 and N5 also provided an adequate sample of material from units 1b and 1c.
- To strengthen data on spatial variability within the shelter, I also recorded all flakes from the uppermost excavation units in N5 through to N18, giving a transect from the rear of the shelter to the lip of the overhang.
- Flakes from QR9 were added to this sample to provide a sample of the larger artefacts tending to accumulate in and around the rock fall in the centre of the shelter.

Raw materials. In the tables below, I have not routinely broken down each analysis by raw material for two reasons. First, my analysis showed this duplicated trends shown by the wider assemblage. At Puritjarra, flaking methods are not strongly differentiated by raw material. It is blank form that is important and this cuts across raw material categories, as Barton (2003: 35) also found in Simpson Desert assemblages. Secondly, the sample is too small to calculate valid statistics for each raw material separately. Even with the larger sample provided by the wider assemblage, the data are often strongly skewed statistically.

Supporting data sets. Not all analyses can be reported in detail in this paper. Results can be checked using the databases listed in Appendix 2 (available on request from the author).

Multivariate analyses were carried out using MV-ARCH (Wright, 1992).

The Lithic Landscape

People visiting Puritjarra made extensive use of local materials for stone artefacts—silicified sandstone, clear quartz and ironstone—but throughout the history of the site they also brought in better quality stone from sources up to 60 km away—white chalcedony, nodular chert, and silcrete (Table 4).

Local materials

The sedimentary rocks forming the rock shelter provided a range of materials:

Silicified sandstone. The dominant raw material in all units is a low-grade orthoquartzite, found locally in beds c. 0.5 m thick within the Mereenie sandstone that forms the rock shelter (and exposed in places within the shelter itself). This material has a good conchoidal fracture. When fresh it is hard and brittle but older implements excavated from layer II during the damp conditions experienced in May 1988 were deeply weathered and had to be left to harden on drying. The immediate source of the silicified sandstone used by inhabitants of the rock shelter appears to have been roof fall, or blocks of stone from the scree slope on the southern side of the rock shelter. Flakes were also removed from the exposed edges of large rock slabs embedded in the floor of the rock shelter.

Black/brown ironstone. Thin beds of a fine-grained ferruginized rock occur near the junction of Mereenie sandstone and the underlying Carmichael sandstone. Locally referred to as ironstone, this material occurs as gravel within the shelter deposits and outcrops at the foot of the escarpment 1 km north of the rock shelter. It mainly occurs in tabular pieces c. 20 mm thick, which limits its utility.

Quartz. Small quartz pebbles c. 30 mm diameter occur in the local sandstone. These were occasionally used as sources of flakes.

Non-local materials

The transported stone provides a broad picture of the catchment used by the inhabitants of the rock shelter (Table

Table 4. Temporal distribution of raw materials at Puritjarra.

analytical unit	n	silicified sandstone %	iron-stone %	quartz %	grey silcrete %	other silcrete %	white chalcedony %	yellow-grey chert %	nodular cherts %	red siltstone %	glass[e] %
1a	7227	50	3	<0.5	6	1	27	6	6	<0.5	<0.5
1b	3794	47	4	<0.5	7	1	29	8	4	—	<0.5
1c	1656	67	4	1	5	1	17	3	1	—	—
2a	1596	49	5	<0.5	30	3	10	2	1	—	—
2b	239	54	6	—	30	5	4	1	—	—	—
2c	42	29	5	—	21	21	19	5	—	—	—
2d	22	64	5	—	27	—	5	—	—	—	—
total assemblage[f]	17069	53	4	<0.5	9	1	23	6	4	<0.5	<0.5

[e] A piece of clear glass (M10/1-7) was found in 1a just below the modern floor of the rock shelter. A retouched piece of green bottle glass (N13/6-1) was also recovered from unit 1b, where it is intrusive and associated with traces of a burnt tree root nearby (Feature N13/8).

[f] Figures for total assemblage include unassigned I and II.

5), although specific stone sources can rarely be identified. The inhabitants of Puritjarra used stone drawn from sources across a wide area west of the main ranges. One of the strongest connections was between Puritjarra and the Putarti Spring/Puli Tjulkurr area, where white chalcedony was obtained, at the end of the main ranges north east of the site (Fig. 1). This was an important link throughout the history of the rock shelter, mirroring a travelling route that Pintupi/Luritja people used in the ethnographic period (Puritjarra-Murantji-Alalya-Mt Udor-Putarti). The grey silcrete and tabular yellow-grey chert probably reflect use of local stone sources in the Cleland Hills or nearby in Watsons Range and the Glen Edith Hills. Other silcretes may have come from the main ranges 70 km east of Puritjarra. The use of nodular cherts suggest visits to the sand hill country south towards Lake Amadeus. Use of the sandhill country west of the Cleland Hills is unlikely to be reflected in the flaked stone at Puritjarra because this area is poor in isotropic stone. More surprising is the rarity of metasediments, vein quartz or igneous rocks from the Arunta complex which outcrop in a broad arc c. 50 km north of the rock shelter (Ranford, 1969).

Grey silcrete. A fine-grained grey silcrete forms a duricrust on sandstone or quartzite ridges throughout the central Australian ranges—especially on Mereenie sandstone and Heavitree quartzite. This is the most common material used for stone artefacts in the main ranges to the east of the Cleland Hills (Smith, 1988) and has often been quarried to produce the large leilira blades used as men's knifes (Graham & Thorley, 1996). In some archaeological studies it is confused with quartzite (Gould & Saggers, 1985; Saggers, 1982) but can be distinguished by its superior flaking properties, its lustre, and by the characteristic groundmass of clear amorphous silica that surrounds the quartz grains. Although useful exposures of this silcrete were not found near Puritjarra, it is likely that they exist elsewhere on the escarpments and sandstone surfaces that form the Cleland Hills. Fine-grained grey silcrete is the dominant material in excavations at the Tjungkupu site, in the Glen Edith Hills 35 km east of Puritjarra, so it must also outcrop in that area (Smith, 1988: chapter 5). Whatever the case, the silcrete entered Puritjarra rock shelter as flakes, small cores or retouched implements suggesting that much of the primary flaking took place elsewhere.

Table 5. Provenance of stone used for flaked stone artefacts at Puritjarra.

analytical unit	local stone[e] %	non-local stone: sources in Cleland Hills %	non-local stone: other regional sources[f] %	n
1a	53	12	34	7226
1b	51	15	34	3793
1c	72	8	19	1656
2a	54	32	14	1596
2b	60	31	9	239
2c	34	26	40	42
2d	69	27	5	22
LGM[g]	76	17	7	122

[e] Available in the rock shelter or nearby.

[f] 50–100 km from Puritjarra.

[g] Included in 2a and 2b but isolated here to show the distinctive pattern of stone usage in levels coinciding with the last glacial maximum.

Other silcretes. These are mainly red, brown or yellow fine-grained silcretes, available as fist-sized nodules or cobbles. This material occurs as a duricrust on sedimentary rocks in the main ranges east of Puritjarra. These silcretes are only a significant component of assemblages in early Holocene and late Pleistocene levels (units 2a–c), where they were brought in as unmodified flakes.

White chalcedony. The most abundant of the transported raw materials is white chalcedony. This is opaline silica, a cryptocrystalline material with strong conchoidal fracture, sometimes called "country opal". It varies from an opaque white chert to a translucent brown or grey chalcedony and occurs throughout the desert lowlands, usually in localized low outcrops. It does not outcrop in the Cleland Hills but several quarries are known to the north and west of this area (Hayden, 1979: fig. 29). The nearest source is a small quarry called Puli Tjulkura, literally "white stone", on the eastern side of Mt Peculiar 60 km to the north east of Puritjarra (Fig. 1). This quarry has not been used since the mid 1930s. Benny Pinapuka Tjapangati, a Pintupi/Kukatja man in his late sixties, specifically identified it as the main source of stone for people living in the Cleland Hills (Law, 2003: 71). He remembered visiting Puli Tjulkura as a boy with his family and walking back to Alalya, Murantji and Puritjarra with the stone, which men carried "tied up in their hair", pushed into the hair buns that young initiated men wore. PIXE-PIGME geochemical analysis confirms Puli Tjulkura as the probable source of the white chalcedony reaching Puritjarra from at least unit 2a onwards (Law, 2003: 66–67, Appendix A). The archaeological evidence shows that people brought pieces of chalcedony, mainly large flakes and shatter blocks <100 g, to Puritjarra rock shelter.

Yellow-grey chert. This is a cherty pedogenic silcrete, with occasional quartz grains set in a mottled yellow-grey chert groundmass. As it formed by induration of an ancient land surface it is widely found in the desert lowlands. This stone reached the rock shelter as large flakes and tabular blocks up to c. 300g. The nearest source has not been identified but there may well be an outcrop in the Cleland Hills, or in the surrounding dune fields.

Nodular cherts. The source of these bright yellow, black, buff, or semi-translucent yellow cherts probably lies in exposures of dolomite and limestone in the sandhill country south or south east of the Cleland Hills. One possibility is the Inindia formation between Watsons Range and Lake Amadeus, c. 60 km from Puritjarra. These cherts only become a significant component of the assemblage in the late Holocene (units 1a and b). The chert reached the rock shelter as small cobbles c. 25–50 mm diameter, often retaining the desert varnish that is characteristic of stones from stony "gibber" land surfaces. The chert cores are small 10–20 g and the size of the flakes and debitage is consistent with primary reduction of chert nodules rather than simply the trimming and resharpening of tools.

Red siltstone. Two flakes of a distinctive dark red siltstone are present amongst the excavated artefacts. There are a number of possible sources in the Cleland Hills and surrounding region, especially in the fine-grained sedimentary rocks of the Larapinta Group.

Metasediments and igneous rocks (not shown in Tables 4 and 5). These materials originate in the Arunta complex, north of the Cleland Hills. At Puritjarra, they are represented by two flakes of dolerite (Z10/3) and a section of a metasediment cobble (surface find)—all probably parts of ground-edged axes—and a trimming flake from a grindstone (ST5/2-3) also of metasediment. None of these finds are earlier than unit 1b.

Temporal changes in raw materials

Over time there is little change in the range of sources used except for the appearance of nodular chert after c. 3,500 B.P. (units 1a and b) (Table 4). However, there is an overall switch in the abundance of certain types of raw materials used for artefacts, from silcrete in the late Pleistocene and early Holocene, to chert and chalcedony in the late Holocene, when c. 40% of all artefacts were made of these materials. This is the product of a long-term trend—beginning around 7,500 B.P.—not simply a feature of the late Holocene (Fig. 5).

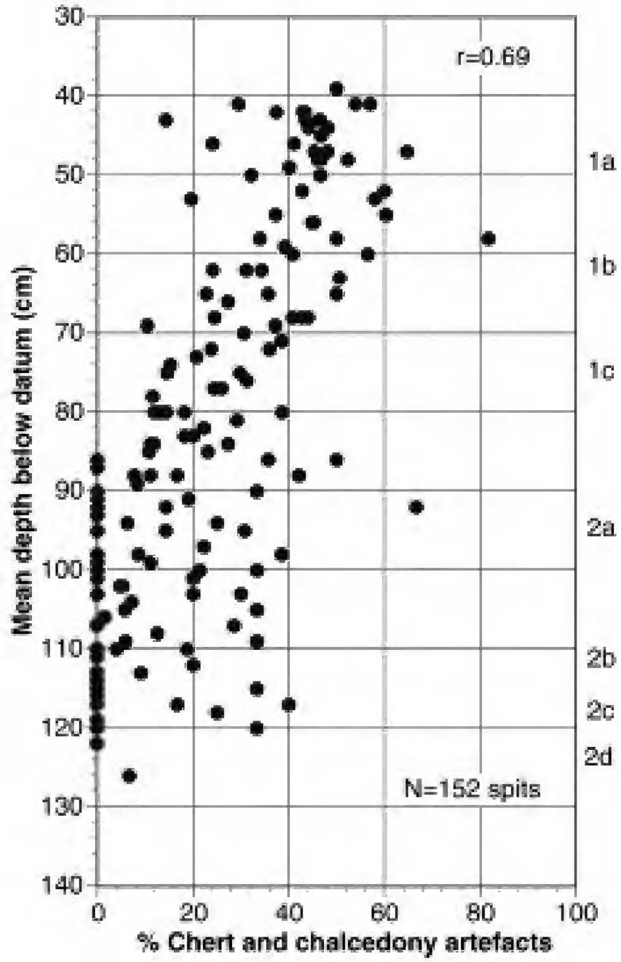
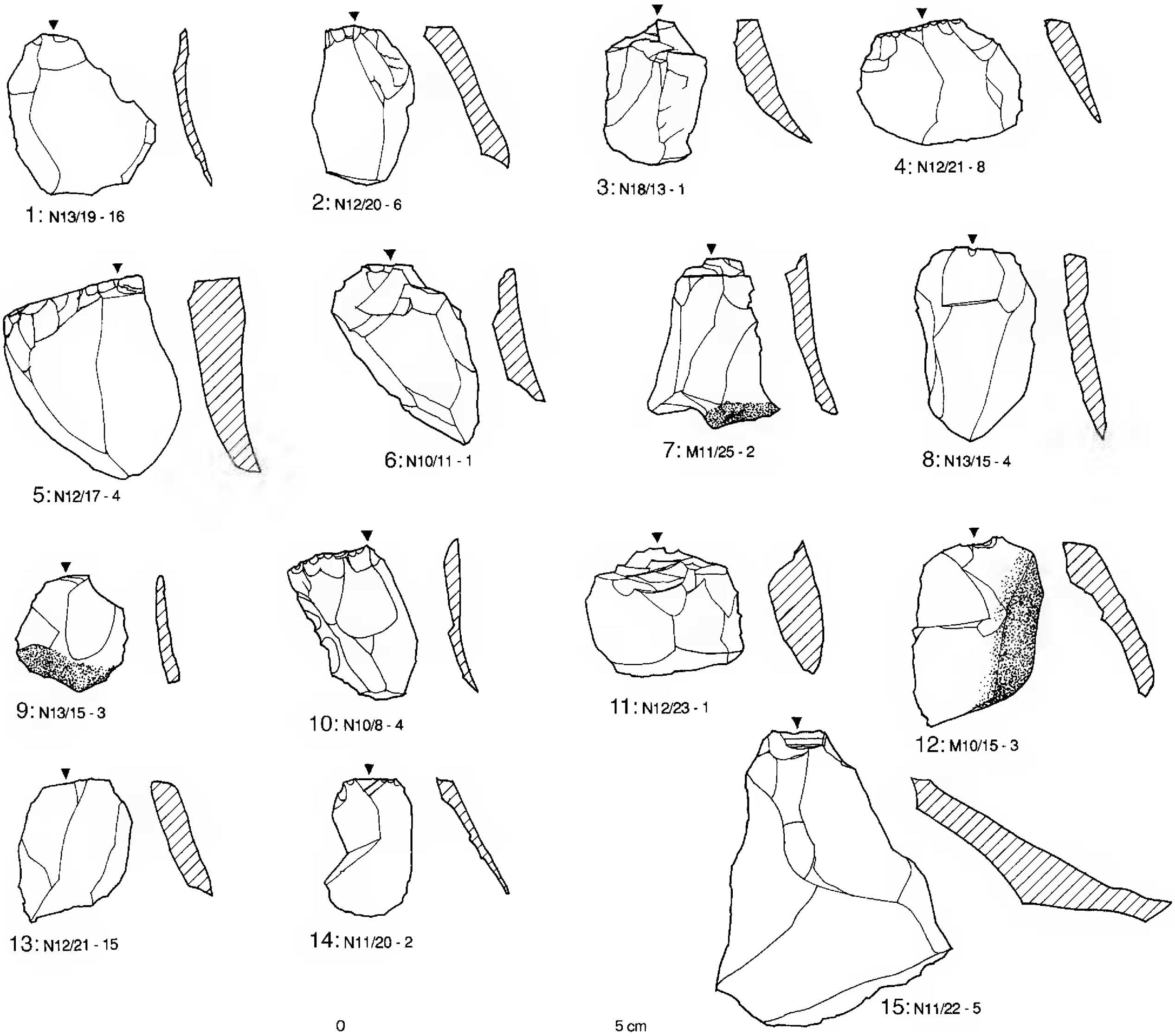


Fig. 5. Graph showing increasing use of chert and chalcedony over time. Data are number of chert and chalcedony artefacts per spit (excavation unit), expressed as percentage of total number of artefacts in each spit. The plot shows data for the Main Trench only (excluding the following: spits without lithics; spits in 2d with only doubtful artefacts, features intrusive from higher levels).



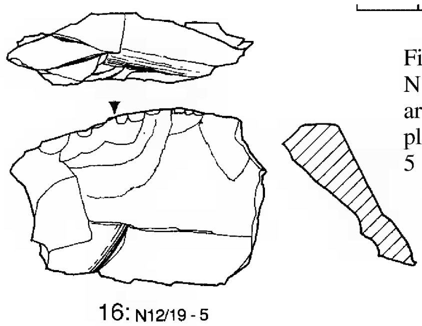


Fig. 6. Small flakes from late Pleistocene levels of Puritjarra rock shelter. From unit 2c: N10/11-1. From unit 2b: N12/21-8, N12/21-15, N12/23-1, N18/13-1, M11/25-2. Remainder are from unit 2a. N12/21-8 and N12/17-4 each have a series of fine flakes scars along the platform edge, showing trimming of an overhang prior to detachment of the flake. N12/19-5 exhibits a facetted platform. N11/22-5 is a sandstone flake struck from a bifacial core.

There are also changes in the relative importance of local versus transported stone (Table 5). People using the rock shelter at c. 32,000 B.P. (unit 2c) made comparatively little use of local sandstone and relied on silcrete and chalcedony from sources north and east of the Cleland Hills. There was greater focus on local stone during units 2a and 2b, particularly during levels coinciding with the last glacial maximum, but there is no evidence for a narrowing of the site catchment during the latter, as the use of materials from distant sources (chalcedony and exotic silcretes) continued.

The use of local stone increased during unit 1c (mid Holocene levels) as use of the rock shelter intensified. This is much as we might expect, as less mobile groups would make more use of local raw material. However, after 3,500 B.P. (in units 1a and 1b) the trend is reversed: local silicified sandstone appears to have been replaced by increasing use of white chalcedony despite a further increase in use of the rock shelter at this time. Possible reasons for this are discussed below (see "History of the rock shelter"). For instance, it may reflect (*a*) greater demand for cryptocrystalline materials imposed by a new tool-kit after 3,500 B.P. (see below); (*b*) changes in the accessibility of white chalcedony at the Puli Tjulkurra quarry; and (*c*) a switch in provisioning strategy from "embedded" procurement of stone (Holdaway & Stern, 2004: 80) to a logistical pattern as use of the rock shelter intensified in units 1a and 1b, or (*d*) greater residential mobility, resulting in more exotic stone being brought into the site.

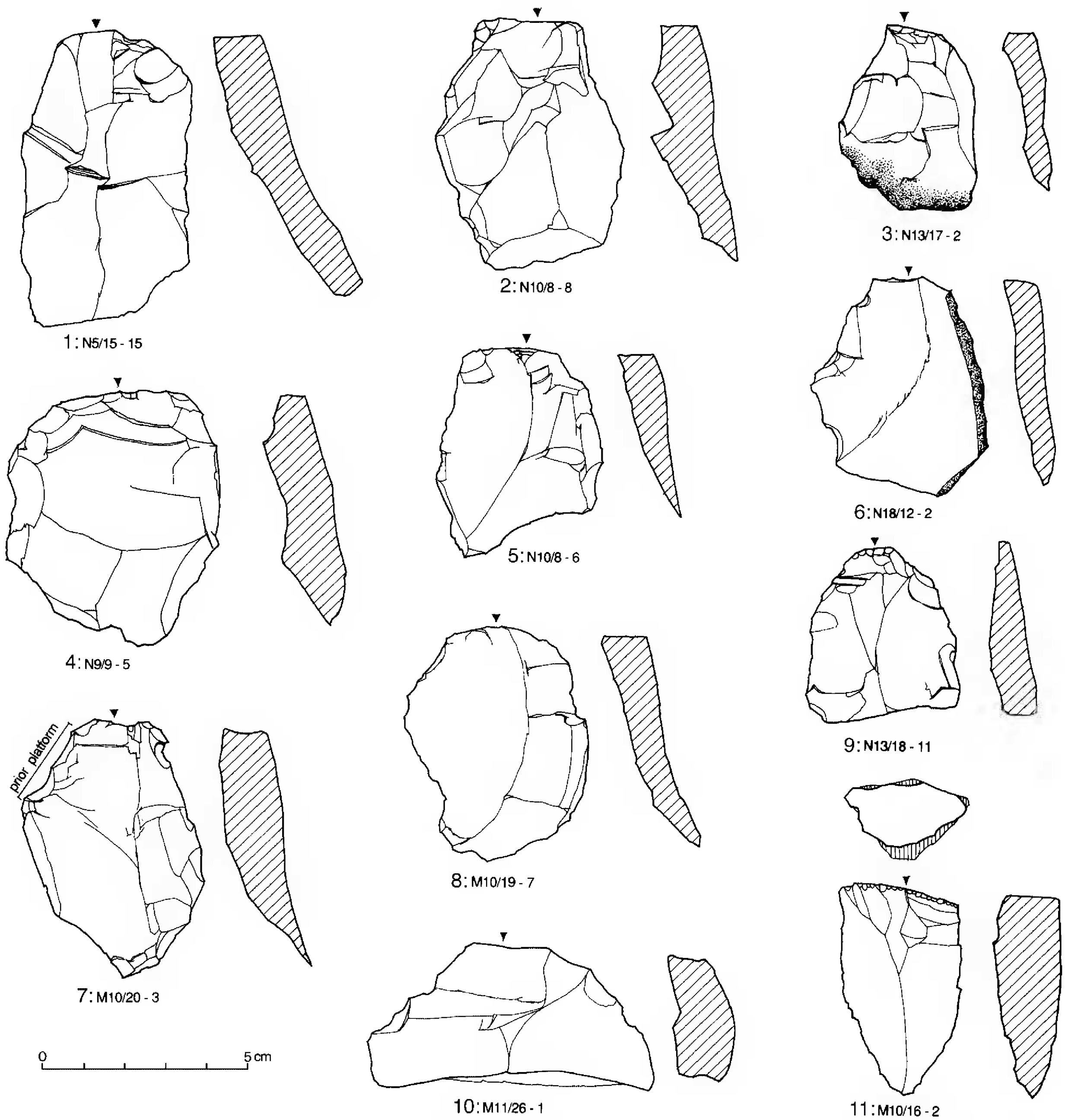


Fig. 7. Large flakes from late Pleistocene levels of Puritjarra rock shelter. All are from unit 2a except M11/26-1 (unit 2b). M10/16-2 is an ironstone flake struck from a horsehoof core, and has fine overhang-removal flaking along the platform edge. M10/20-3 is chert flake with evidence of a prior platform, showing that the core was rotated before this flake was detached.

Flake and core technology

Flakes. Flaking methods show little change over time. The inhabitants of the rock shelter generally produced small rectangular flakes with narrow platforms, often with crushing and step-flaking around the platform and with platform angles between 70° and 80° (Figs 6–8). There is an overall consistency in the *form* of the Puritjarra flakes throughout the history of the site (Table 6). This uniformity reflects generalized but not ad hoc flake production: there is little evidence for the uncontrolled shattering of blocks of stone described by Tindale at the Pulanj Pulanj quarry in the Tomkinson Ranges (1965: 139–143). Nor is there evidence for specialized flaking techniques or the manufacture of standardized blanks, such as blades, lancet flakes, or the large "potlid" flakes used for tula adzes. Bipolar flaking is absent: a bipolar core previously reported for N10/3 has been re-examined and is part of a broken retouched artefact rather than a core. A small number of flakes (<2%) have facetted platforms (e.g., N12/19-5, Fig. 6-16). Around 5–10% of flakes also bear small regular flake scars along the platform edge showing where the edge of a core has been trimmed prior to flake detachment (N12/21-8 and N10/8-4, Figs 6-4 and 6-10; M10/16-2, Fig. 7-11). Neither of these techniques shows a strong chronological trend.

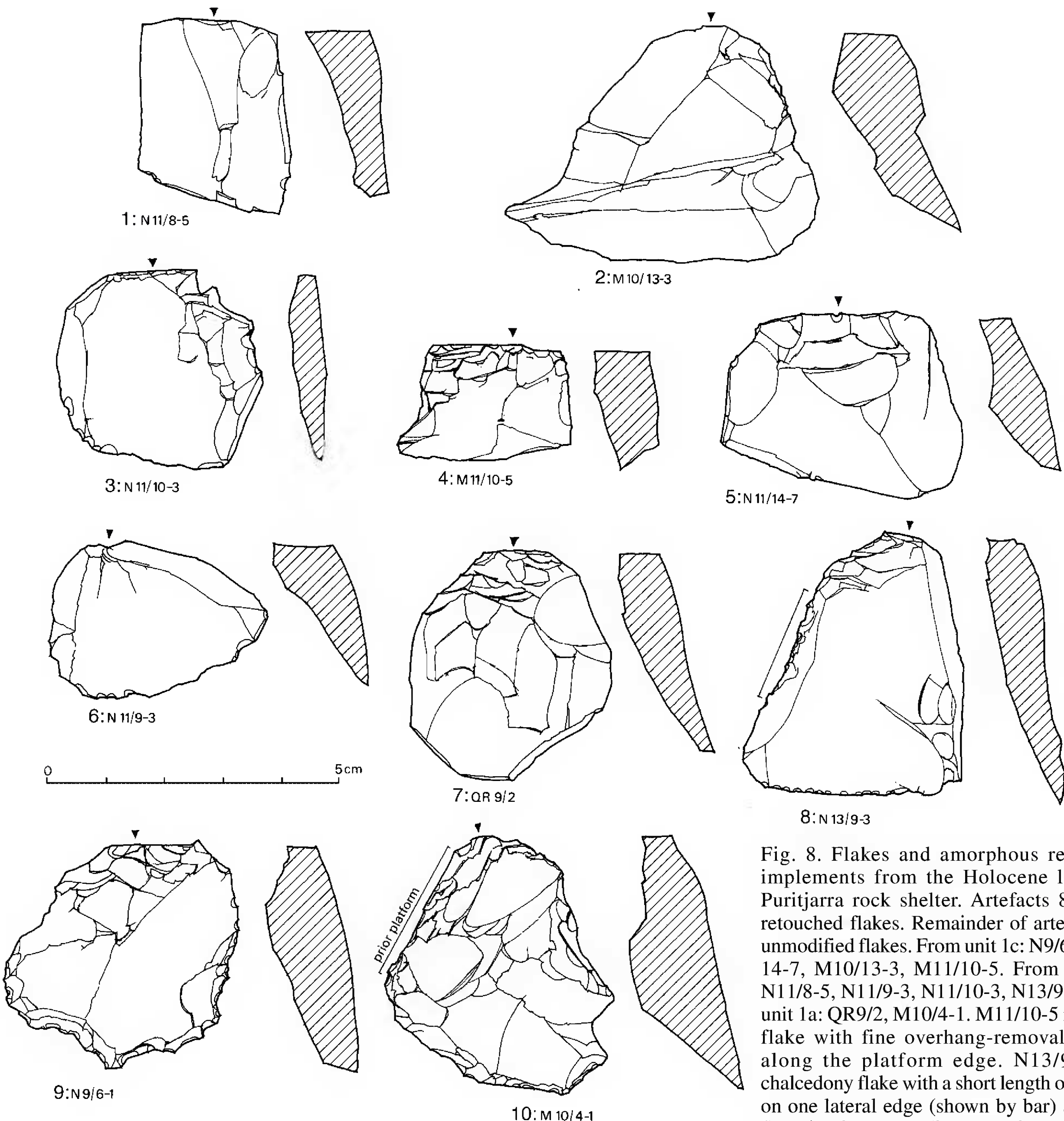


Fig. 8. Flakes and amorphous retouched implements from the Holocene levels of Puritjarra rock shelter. Artefacts 8–10 are retouched flakes. Remainder of artefacts are unmodified flakes. From unit 1c: N9/6-1, N11/14-7, M10/13-3, M11/10-5. From unit 1b: N11/8-5, N11/9-3, N11/10-3, N13/9-3. From unit 1a: QR9/2, M10/4-1. M11/10-5 is a chert flake with fine overhang-removal flaking along the platform edge. N13/9-3 is a chalcedony flake with a short length of retouch on one lateral edge (shown by bar) and with fine nibbling along distal margin. M10/4-1 is a retouched chalcedony flake exhibiting a prior platform.

Fine-grained silcrete, yellow-grey chert and white chalcedony show similar patterns of flaking, though there is greater variability and a wider size-range for flakes made on local silicified sandstone (Table 7). Student's-t tests indicate there is no significant difference in mean flake weight, comparing white chalcedony and grey silcrete (t = 0.0946, $t_{0.05(2),192}$ = 1.973) or grey silcrete and yellow-grey chert (t = 0.7477, $t_{0.05(2),152}$ = 1.976) (Table 7—all units combined).

In a previous report (Smith, 1989: 99), two flake facies amongst the late Pleistocene/early Holocene artefacts were distinguished: small flakes c. 30 mm long made on imported silcrete or chalcedony; and large flakes c. 80 mm long made on local sandstone and silcrete. Both facies involved flakes struck from well set up and maintained platform cores. Now that a larger sample of excavated material is available we can see that these facies are part of a continuum: no bi-modality is evident in flake size, whether we use weight or flake length to estimate this. Although their relative importance varies both kinds of flakes are present throughout units 2a–d and into 1c.

Temporal trends. Flakes in late Pleistocene levels (units 2b–d) are small and well made with an emphasis on fine-grained silcrete—similar to late Pleistocene flakes at Kulpi Mara (Thorley, 1998b: 236). Over time there is a trend from 2a to 1a towards smaller flakes (Fig. 9). This is partly because flakes in unit 2a are more variable in size than those in other units and include many large flakes >40 mm long (mainly made on local sandstone or ironstone). These large flakes are less common in units 1c and 2b–d but still

Table 6. Flake attributes, (n = 764). Data are for all complete unmodified flakes included in the attribute study, except 5 flakes at the base of layer II (unit 2d), which may not be cultural artefacts. All figures are mean values except where indicated otherwise. As these data are strongly positively skewed, median weight is given for comparison.

analytical unit	n	median weight g	mean weight g	L mm	B mm	Th mm	platform thickness mm	exterior platform angle	L/B ratio	flare[e]
1a	229	1	3±6	21±10	18±8	5±4	5±3	72°	1.3	1.6
1b	74	2	4±7	23±10	20±9	6±4	6±5	71°	1.2	1.8
1c	84	3	8±13	27±14	24±12	7±5	7±5	68°	1.2	1.5
2a	286	4	12±19	30±15	27±13	7±5	7±5	75°	1.2	1.6
2b	69	2	4±6	23±9	20±10	5±3	5±4	71°	1.3	1.8
2c[f]	8(6)	2	24±36(3)	35±20(24)	26±13(19)	9±9(4)	7±9(3)	72°(74°)	1.4(1.4)	2.0(2.2)
2d	4	1	3±4	20±8	18±13	4±3	6±4	76°	1.4	1.4
unassigned II	10	1	2±2	19±6	18±4	3±2	4±2	74°	1.1	1.4

[e] This is Hiscock's parallel index (1986:48), calculated by dividing flake breadth by platform breadth. Values <1 indicate a flake that converges to a point. Values >1 indicate a flake with a distal flare.

[f] Values for unit 2c are skewed by 2 large sandstone flakes >85g. Figures in brackets exclude these.

represent a significant component of these assemblages. In contrast, the majority of flakes in units 1a and 1b fall between 10 and 30 mm in length. This size trend (expressed in terms of weight in Table 7) is also evident in the sandstone flakes and does not simply reflect greater use of chert and chalcedony in the late Holocene.

Flakes from units 1a–c also tend to have come from more heavily worked cores than those in earlier levels: there is more evidence of core rotation, more dorsal scars on the flakes, and more artefacts with flaked platforms. A multivariate (canonical variates) plot (Fig. 10) shows the centroids for 5 groups of flakes and plots these against flake variables: raw material grain-size, flake weight, percentage cortex, length, breadth, thickness, platform breadth, platform thickness, exterior platform angle, platform preparation, overhang removal, evidence of core rotation, and the number of flake scars on the dorsal surface. Vector 1 represents reduction stage. Flakes on the left-hand size of the plot tend to have come from heavily worked cores. Vector 2 represents flake size. Artefacts towards the top of the plot are larger flakes, with larger platforms, and tend to be on granular materials such as sandstone or silcrete. The overall trend over time is for smaller flakes, detached from more heavily worked cores, with more frequent use of fine-grained or cryptocrystalline materials. One anomaly in this pattern is that the frequency of cortex is not correlated with flake size. This is because most flakes in this assemblage are tertiary flakes and there are few decortication flakes at any level (Table 8).

Cores

There are only a limited range of cores present in the Puritjarra assemblage (Figs 11 and 12) and these show little change over time apart from a trend towards more intensive reduction of cores in the Holocene. The major types described below are consistent with the range of cores described for neighbouring parts of the arid zone (Barton, 2003; Cane, 1984, 1992; Gould, 1977; Smith, 1988).

Amorphous cores. These cores do not have discrete striking platforms and there is no detectable pattern in flaking. Essentially, they reflect opportunistic flaking of local sandstone. Flakes have been removed haphazardly from any convenient face, each flake from a different point on the core.

Bifacial cores. In this technique flakes have been detached from alternate faces along an edge. Heavily worked cores acquire a distinctive discoidal form with a sinuous edge (N5/22-1, Fig. 11.2), but many of the cores at Puritjarra were discarded before this state was reached. The method was mainly used for slabs of local sandstone and is an effective way of removing flakes along an edge with minimal preparation of the piece. As a result these cores are very variable in size (from 6 g to 4 kg) and size of the core bears little relation to the size of the flakes produced (20–40 mm long).

Table 7. Variation in flake weight by raw material and unit, (n=603). Data are for complete unmodified flakes included in the attribute study. Only the most common raw materials are shown.

analytical unit	silicified sandstone n	silicified sandstone mean wt (g)	grey silcrete n	grey silcrete mean wt (g)	white chalcedony n	white chalcedony mean wt (g)	yellow-grey chert n	yellow-grey chert mean wt (g)	nodular chert n	nodular chert mean wt (g)
1a–b	156	5±8	32	1±1	51	1±1	26	2±3	23	1±1
1c	63	10±14	4	1±1	10	2±2	2	2±1	1	0.8
2a	174	14±19	52	5±12	14	4±7	6	12±25	—	—
2b–d	36	8±16	29	2±1	2	4±4	2	1±0.3	—	—
all units combined[a]	437	10±15	117	3±9	77	2±4	37	4±11	25	1±1

[a] n=693. These figures include flakes from "unassigned II".

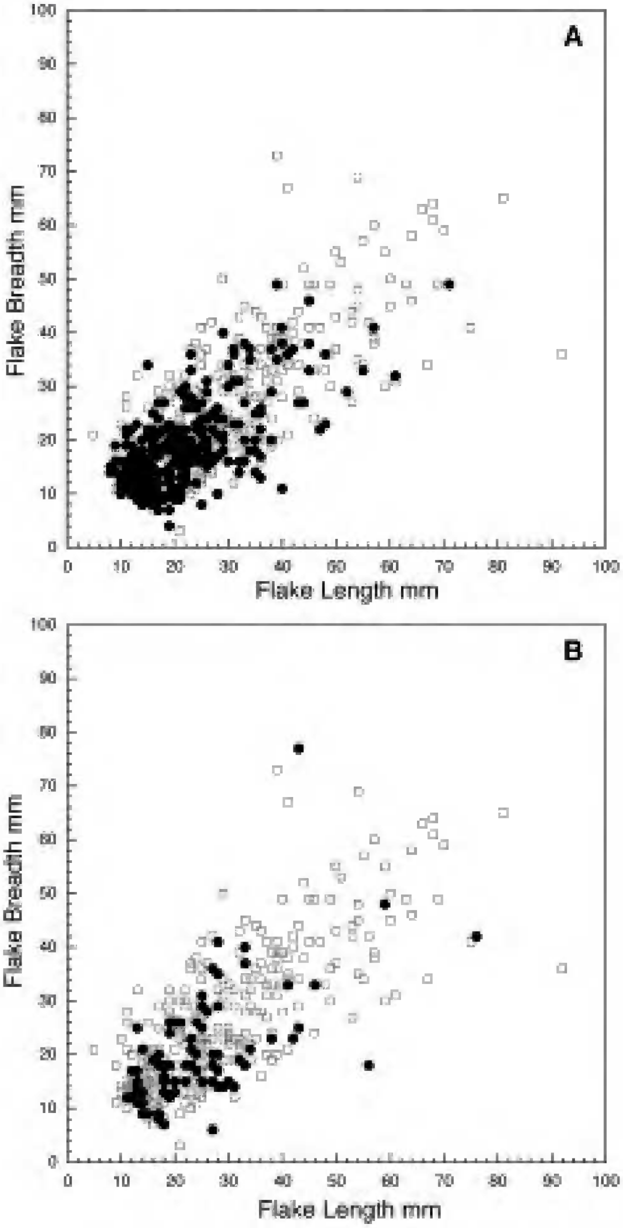


Fig. 9. Flake size and shape by analytical unit. Data are length/breadth measurements for a representative sample of 769 complete flakes. (*A*) Comparison of units 1a–b (solid grey circles), and unit 2a (open squares). Late Holocene flakes are smaller and less variable in size than early Holocene/terminal Pleistocene flakes, but have similar proportions. (*B*) Comparison of units 2b–d (solid grey circles) and unit 2a (open squares). Late Pleistocene flakes are smaller than those in the early Holocene/terminal Pleistocene, but have similar variability and proportions.

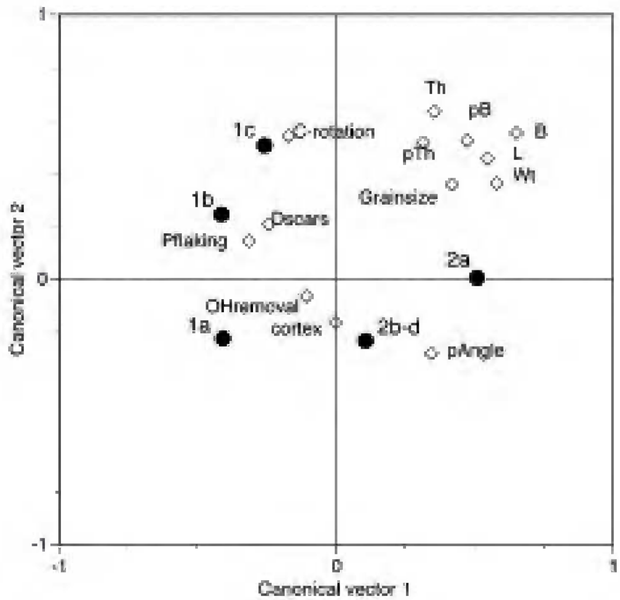


Fig. 10. Multivariate analysis of flake attributes, using the Canonical variates program in the MVARCH package. Data are for flakes where the full set of platform and flake attributes can be measured (N = 635). Scatter-plot shows the centroids for groups of flakes from each unit plots these against flake variables—raw material grain-size, flake weight, percentage cortex, length, breadth, thickness, platform breadth, platform thickness, platform angle, platform preparation, overhang removal, evidence of core rotation, and the number of flake scars on the dorsal surface.

Single platform cores. These cores result from the use of a bedding plane, or the ventral surface of a large flake, as a striking platform and the detachment of flakes down the face of the block. The majority of the cores at Puritjarra are single platform cores of one form or another. They range from cores on otherwise unmodified pieces of sandstone or silcrete (N13/19-1, N11/19-2, N9/9-3, N5/15-2) (Figs 11.1, 11.3, 11.5 and 11.8) to prepared cores showing evidence of attempts to prepare the core prior to flaking, by shaping the face of the core, modifying the platform or trimming the edge of the platform (N5/15-10, N9/9-2, ST5/4-4) (Figs 11.4, 11.7, 12.2). Chert or silcrete cores tend to be more heavily worked than those on sandstone, though many of the latter are also well developed (N13/19-1, N5/15-2, ST5/4-4) (Figs 11.1, 11.8, 12.2). From the early Holocene/terminal Pleistocene levels (unit 2a) there are several cores of grey silcrete (Z10/7-4, N9/9-2) (Figs 11.6, 11.7), of the type used to produce the small silcrete flakes shown in Fig. 6, for example, N9/9-2 (30 g). The platform on this core has been prepared by flaking, the overhang has been removed to facilitate knapping, and the removal of flakes extends around most of the perimeter of the core. From the flake scars we can see that this core produced flakes up to 22–25 mm long, with length/breadth ratios up to 2.8.

Multi-platform cores. Where a platform has given problems, a second platform has often been initiated on another face of the core. The majority of these multi-platform cores are ironstone or sandstone, reflecting the greater difficulty of flaking tough granular stone and the higher rate of platform failure on these materials.

Horsehoof cores. These are single or multi-platform cores with extensive step flaking undercutting the platform (N9/9-3, ST5/3-4, QR9/1-3) (Figs 11.5, 12.1, 12.4). The characteristic step flaking on these cores results when flakes repeatedly fail to run the length of the core. Unless a knapper can correct the flaw each step becomes a focus for further flake failure. At Puritjarra, "horsehoof" cores make up only a small component of the assemblage and are probably worked-out or "exhausted" cores. Although I have restricted the term to cores where the platform has been substantially

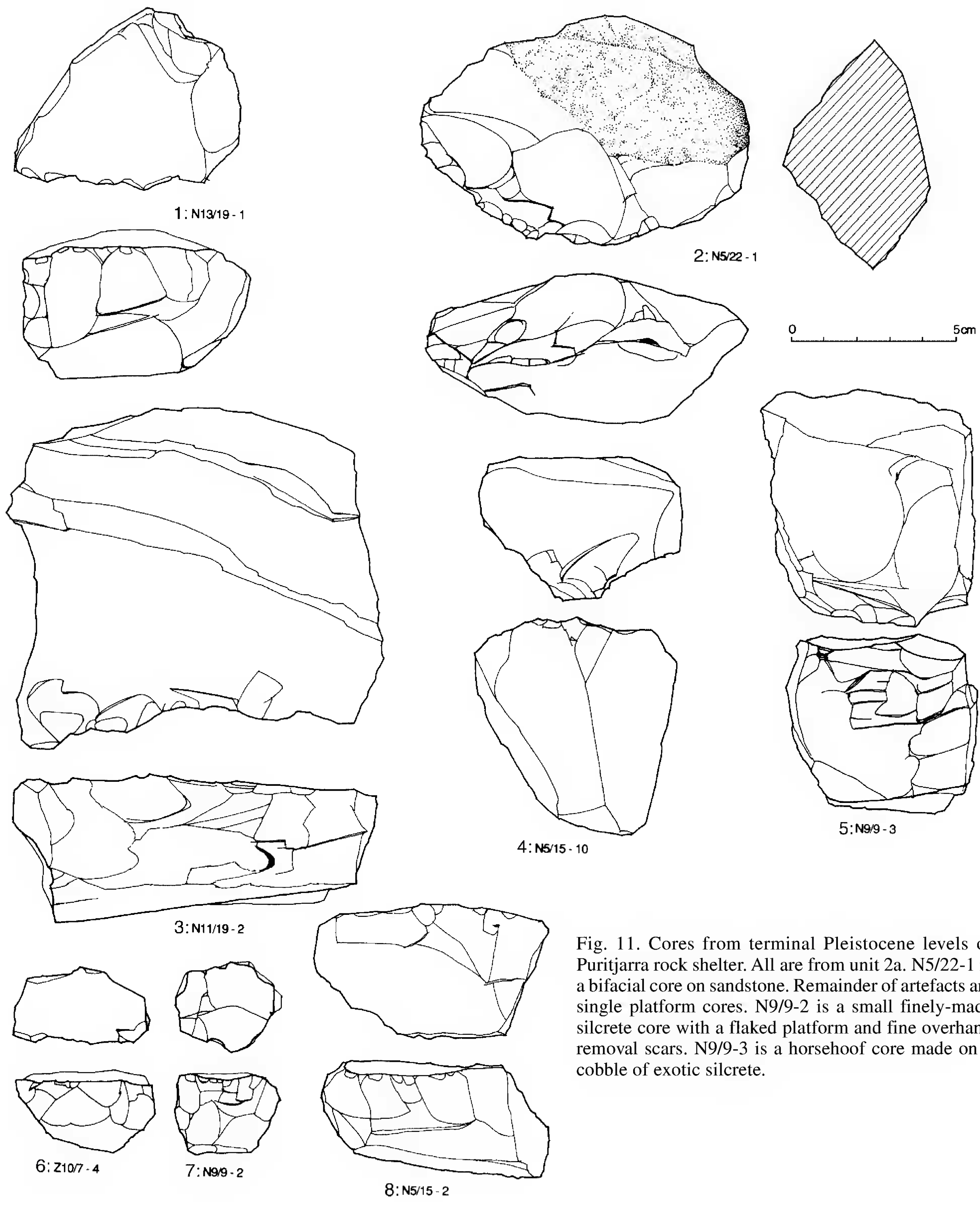


Fig. 11. Cores from terminal Pleistocene levels of Puritjarra rock shelter. All are from unit 2a. N5/22-1 is a bifacial core on sandstone. Remainder of artefacts are single platform cores. N9/9-2 is a small finely-made silcrete core with a flaked platform and fine overhang removal scars. N9/9-3 is a horsehoof core made on a cobble of exotic silcrete.

reduced by step-flaking, nested step-fractures are also evident on other platform cores (N13/19-1, ST5/4-4) (Figs 11.1, 12.2), showing that the "horsehoofs" are one end of a continuum in this assemblage.

The cores confirm the picture provided by the flakes. There is no evidence for specialized flake production, blades or bipolar techniques. The cores show a basic continuity in flaking methods and types of core preparation (Tables 9 and 10). The main chronological trend is towards heavier working of cores in the mid to late Holocene levels. Rotated or exhausted cores are more common in units 1a–c (Table 9). There is also a higher percentage of broken cores in these levels (e.g., N5/6-2, Fig. 12.8) (Table 10) and more cores with step-fractures around the platform (13% in 2a, 18% in 1c, 21% in 1b and 9% in 1a).

The use of cryptocrystalline cores increased in the late Holocene and there is a corresponding decline from unit 2a to units 1a–b in the mass of cores and in the size of the flakes detached from these cores (Table 10). This reflects more intensive reduction of cores in Holocene contexts not

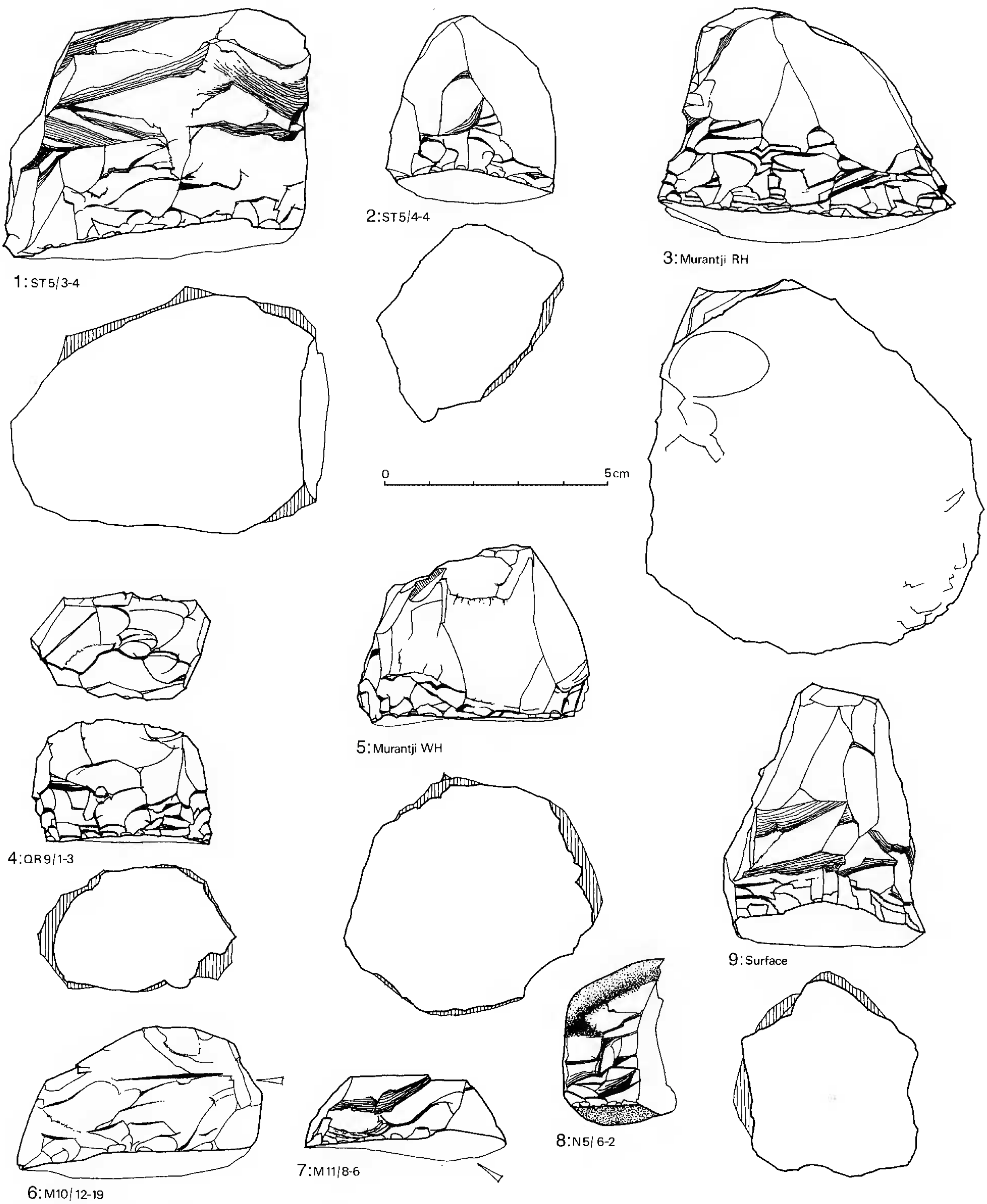


Fig. 12. Cores and redirecting flakes from the Holocene levels of Puritjarra rock shelter or from nearby Murantji rock hole. From unit 1a: QR9/1-3. From unit 1b: M11/8-6, N5/6-2. From unit 1c: M10/12-19. Unassigned 1b–c: ST5/3-4, ST5/4-4. M10/12-19 and M11/8-6 are sandstone redirecting flakes. N5/6-2 is a single platform core split during knapping. QR9/1-3 is a small horsehoof core, with a base (shown) reduced as a bifacial core. The large platform core from Murantji (3) is on a flake of yellow-grey chert.

simply a shift to finer-grained raw materials. For instance, although cores of silcrete and sandstone are larger on average than those made on chert and chalcedony (Table 11) they also became smaller after unit 2a. Multivariate analysis of the cores, using canonical variates, indicates an overall trend from unit 2a to 1a–c from large granular cores with cortex to smaller fine-grained cores discarded later in the reduction sequence with more frequent core rotation, larger platform angles and more frequent flaking of platforms.

Table 8. Flake stage, (n=515). Primary flakes have >50% cortex on dorsal surface. Secondary flakes are flakes with 1–50% cortex. Tertiary flakes have no cortex remaining on the dorsal surface.

	n	primary flakes %	secondary flakes %	tertiary flakes %
Unit 1a (late Holocene)				
All complete flakes	229	6	15	79
Grey silcrete flakes	24	4	21	75
Chalcedony flakes	38	8	26	66
Silicified sandstone	171	6	10	84
Unit 2a (Terminal Pleistocene)				
All complete flakes	286	7	13	80
Grey silcrete flakes	52	6	15	79
Chalcedony flakes	14	0	29	71
Silicified sandstone	189	8	13	79

Comparison of the cores and flakes identifies some missing elements of the assemblage. The Puritjarra assemblage, like most excavated artefacts, comprises the material that people discarded on-site rather than a representative sample of a stone industry. There is an overall correlation between the size of flakes and the size of cores in units 1a–1b but not for earlier levels. In units 2a–d there are few platform cores large enough to have been the source of the large flakes >50 mm found in these levels (except N5/15-10, Fig. 11.4). These flakes are on a range of materials. Silicified sandstone and ironstone predominate but there are also large flakes of grey silcrete, red/yellow silcrete, chalcedony and yellow-grey tabular chert. The large sandstone flakes probably derive from flaking of the boulders on the floor of the rock shelter. For other materials, it is possible that the cores remained in circulation and were carried away from the site. A chert core from nearby Murantji rockhole represents the sort of artefact missing from the excavated assemblage (Fig. 12.3). An alternative possibility is that large flakes were brought to the rock shelter rather than manufactured there. In units 2a–c the paucity of debitage from the working of chert, chalcedony or exotic silcrete suggests this is the more likely explanation.

In the late Holocene levels of the rock shelter, cores of nodular chert and yellow-grey chert are under represented (N=4) given the evidence for on-site flaking of this material. These small chert cores must have been curated and carried away from the site. In an ethnographic study in the northern part of the desert, Cane noted that his Gugadja informants had carried blocks of chert with them as they travelled but when people were more than a day's walk from an outcrop or quarry (about 15 km) access to fresh stone became more difficult. People then held onto their cores until worked out, explaining they had to "knock him, knock him" because there was "no djimeri this country" (Cane, 1984: 248). A similar process may have operated at Puritjarra in the recent past. In units 1a and Ib, there is no evidence to indicate chert cores have simply been worked to destruction: no bipolar reduction, no fragments of cores, broken cores are rare.

Redirecting flakes

Redirecting flakes result from the rotation of a core and subsequent removal of a flake running along the platform edge. Throughout the Puritjarra sequence most redirecting

Table 9. Number of cores by type and analytical unit.

analytical unit	n	amorphous cores	bifacial cores	single platform cores	multi-platform cores[e]	exhausted cores (horse-hoof morphology)[f]
1a	34	5	10	16	2	1[g]
1b	14	2	2	8	—	2
1c	11	1	1	5	3	1[h]
2a	39	5	7	23	3	1
2b	2	1	—	1	—	—
2c	—	—	—	—	—	—
2d	1	—	1[i]	—	—	—
unassigned layer I	28	5	2	16	3	2
unassigned layer II	2	1	—	1	—	—
total number	131	20	23	70	11	7

[e] These all have 2 platforms.
[f] Single platform cores unless indicated.
[g] One core (QR9/1-3) has also been worked as a bifacial core.
[h] Includes one core (N11/13-1)with 3 platforms.
[i] Doubtful artefact excluded from analysis.

Table 10. Core attributes. Data for complete cores are mean values unless otherwise indicated.

unit	complete cores					all cores				
	n	median weight g	mean weight g	core height mm	largest flake scar (L) mm	n	platform angle	granular stone[e] %	crypto-crystalline stone[f] %	broken cores %
1a	29	78	108±113	33±13	29±12	34	74°	74	26	15
1b	7	66	97±119	31±14	27±12	14	79°	50	50	50
1c	10	80	117±97	37±12	36±13	11	74°	82	18	9
2a	37	214	357±535	44±15	34±12	39	73°	95	5	5
2b	2	108	108±36	44±1	40±3	2	80°	100	0	0

[e] Silcrete and silicified sandstone.
[f] Chalcedony and chert.

flakes appear to have come from small or medium sized cores. Two large redirecting flakes removed from horsehoof cores are shown in Figs 12.6 (M10/12-19) and 12.7 (M11/8-6). There are proportionately more chert redirectors in units 1a and 1b than in earlier units (1a and 1b: 46%; 1c and 2a: 21%). In these levels the redirectors are also smaller and shorter reflecting the use of small chert cores.

Implements

The earliest tools (or fragments of tools) are from the palaeosurface dating to c. 32,000 B.P. (unit 2c) (Fig. 13). These include a chalcedony flake with a short length of shallow step-flaking or edge damage (M11/27-2), and a trimming flake of chalcedony (M11/27-4) struck off a tool that must have had a convex scraper edge with fine scalar retouch (Figs 13.2 and 13.4 respectively). From other levels prior to the last glacial maximum (unit 2b), there is a steep-edged scraper made on a thick sandstone flake (N10/11-4) and a thick step-flaked implement with a broad notch (N13/20-1, Fig. 16.6). Retouched artefacts are more common in terminal Pleistocene levels (2a) where they include steep-edged scrapers, notched implements, saws and a range of amorphous retouched or utilized artefacts. Irrespective of the type of implement, the tools in unit 2a are typically large thick flake implements >50 g, including steep-edged scrapers (QR9/8-2, N5/15-11, N11/22-2, QR9/8-11) (Figs 15.3, 15.4, 16.2, 16.3), saws (N10/9-1) (Fig. 16.9), and amorphous retouched implements (M10/22-2, N5/15-12) (Figs 15.2, 16.5). These types continue throughout the Puritjarra sequence but are joined by a suite of smaller finely worked hafted tools at c. 3,500 B.P. (Table 12, Group 2) and new types of grindstones for processing seeds (Smith, 2004). This new suite of tools is characteristic of late Holocene assemblages throughout central Australia (Smith, 1988) and is a regional variant of what is often termed the Australian small-tool phase (Mulvaney & Kamminga, 1999: chapter 14).

Cross-correlation of implement types. The spatial and temporal associations evident in a correlation matrix (Table 13)—generated by analysing the co-occurrence of implement types within the 336 excavation units (spits) at Puritjarra—suggest that there are two groups of implements at Puritjarra:

Group 1: Steep-edged scrapers, notched tools and saws.

Group 2: Geometric microliths, tula adze slugs, thumbnail scrapers and endscrapers.

This is a basic division between tools where only an edge has been modified and those that have been more intensively shaped. Amorphous retouched implements cut across this division and are associated with woodworking implements in both groups (tula adze slugs, thumbnail scrapers, steep-edged scrapers and notched implements). This is not especially surprising. The retouch on the amorphous retouched implements most likely represents use damage (utilization) or resharpening (Hayden, 1977) and this is more likely to have occurred on flakes used for woodworking than those used for cutting flesh or fibre.

Group 1 implements

Group 1 implements form a suite of hand-held woodworking tools. They were used throughout the Puritjarra sequence and show the same shift towards smaller artefacts and greater use of cryptocrystalline stone shown by the flakes and cores.

Table 11. Variation in core size by raw material and unit. Data are for complete cores.

analytical unit	silicified sandstone		grey silcrete		white chalcedony		yellow-grey chert		nodular chert	
	n	mean wt g	n	mean wt g	n	mean wt g	n	mean wt g	n	mean wt g
1a–b	25	124±117	2	42±36	4	11±9	3	130±133	1	9.1
1c	7	125±106	—	—	—	—	1	33	—	—
2a	28	411±597	3	38±11	1	64	—	—	—	—
2b	2	108±36	—	—	—	—	—	—	—	—
total assemblage	84	241±383[e]	6	96±129	6	18±21	6	86±105	2	9±0.2

[e] This figure excludes M10/28-1, a bifacial core on a large sandstone block, weighing 4.1 kg, from 2d.

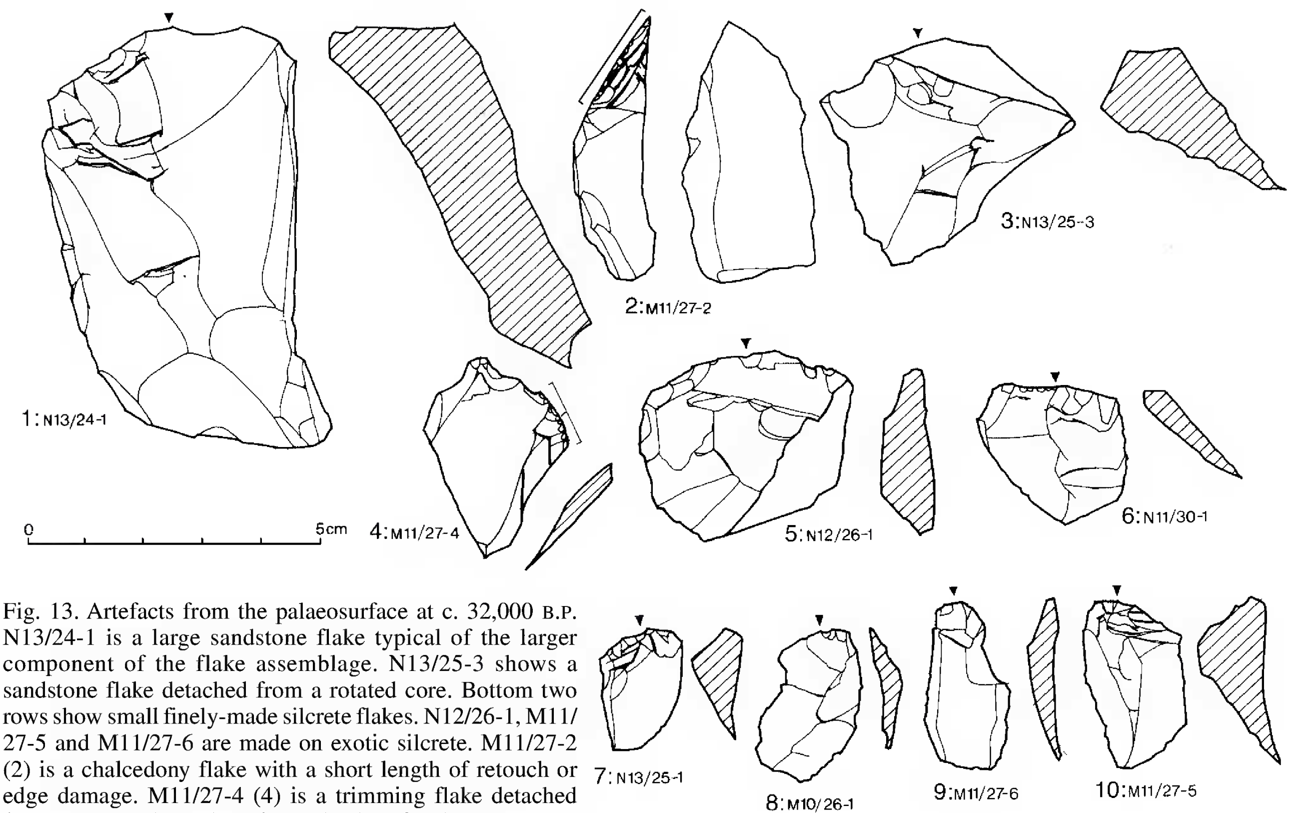


Fig. 13. Artefacts from the palaeosurface at c. 32,000 B.P. N13/24-1 is a large sandstone flake typical of the larger component of the flake assemblage. N13/25-3 shows a sandstone flake detached from a rotated core. Bottom two rows show small finely-made silcrete flakes. N12/26-1, M11/27-5 and M11/27-6 are made on exotic silcrete. M11/27-2 (2) is a chalcedony flake with a short length of retouch or edge damage. M11/27-4 (4) is a trimming flake detached from the retouched edge of a chalcedony implement.

Steep-edged scrapers. Implements with robust, steeply angled, step-flaked edges (cf. Holdaway & Stern, 2004: 230) are common throughout the Puritjarra sequence, but the form and presumably therefore the function of these tools changes over time. Ethnographic and experimental studies suggest implements of this type functioned as heavy duty woodworking tools (Hayden, 1977; Thomson, 1964; Tindale, 1941), and that the characteristic step-flaking results from edge damage or the resharpening of a steep edge rather than deliberate shaping of the tool. The implements from units 2a and 2b are thick artefacts with straight or concave edges, edge angles of >80°, and with step-flaking and crushing along the working edge. Many are made on large thick flakes of local sandstone, but there are also examples on yellow-grey chert (N11/19-1, Fig. 16.1), crystal quartz and chalcedony. In units 1a and 1b the steep-edged scrapers (Fig. 17) tend to be smaller implements (<20 g) made on medium-sized flakes, pebbles or small tabular blocks, usually of chert or chalcedony (64% in units 1a and b). Some are so small (57% <10 g in 1a) that they must have been hafted to have sustained the heavy step-flaking that is evident on their working edges. Unlike the implements from unit 2a, few late Holocene scrapers have concave working edges (23%); the majority have straight or convex edges. Table 14 suggests a trend over time to smaller implements with a concomitant reduction in the length of retouched edges. The pattern of use of these implements also changed over time. Most scrapers in unit 2a have >1 retouched edge. The Holocene implements tend to have only a single working edge, and there was a higher rate of breakage of these tools (Table 14). Overall, these changes probably reflect a change from hand-held woodworking implements towards the small, hafted scrapers or chisels used in the ethnographic period for trimming spear shafts and other wooden implements.

Notched artefacts. These are artefacts with one or more prominent notches formed by retouch, stepping or crushing on an edge (cf. Holdaway & Stern, 2004: 236–238). They are assumed to have functioned as spokeshaves on narrow spear shafts (Holdaway & Stern, 2004: 237–238; Mulvaney & Kamminga, 1999: 217). This is consistent with notch widths <20 mm. These implements were made on a variety of raw materials without regard for the form of the blank. Implements in units 1a and 1b are smaller than the notched implements in 2a but this is essentially a difference in the size of the blanks rather than notch dimensions (Table 14). The implements in 2a have slightly wider and deeper notches but the differences are too slight to be archaeologically significant. Like steep-edged scrapers, the pattern of use of notched implements seems to have changed over time. However, in this case, the late Holocene implements often have a second working edge and fewer are broken than those in terminal Pleistocene contexts (Table 14).

Saws. These are artefacts with finely dentated edges, made on flakes of local silicified sandstone, with regularly-spaced teeth c. 5 mm apart and 1–2 mm high on straight or convex edges (N10/9-1, N5/19-1, Figs 16.9 and 16.11) (cf. Holdaway & Stern, 2004: 238). Although saws are numerically not very important in the Puritjarra assemblage, they represent one of the few types of tools that can be said to have been carefully and deliberately trimmed to a predetermined form. The implements in units 1a and 1b

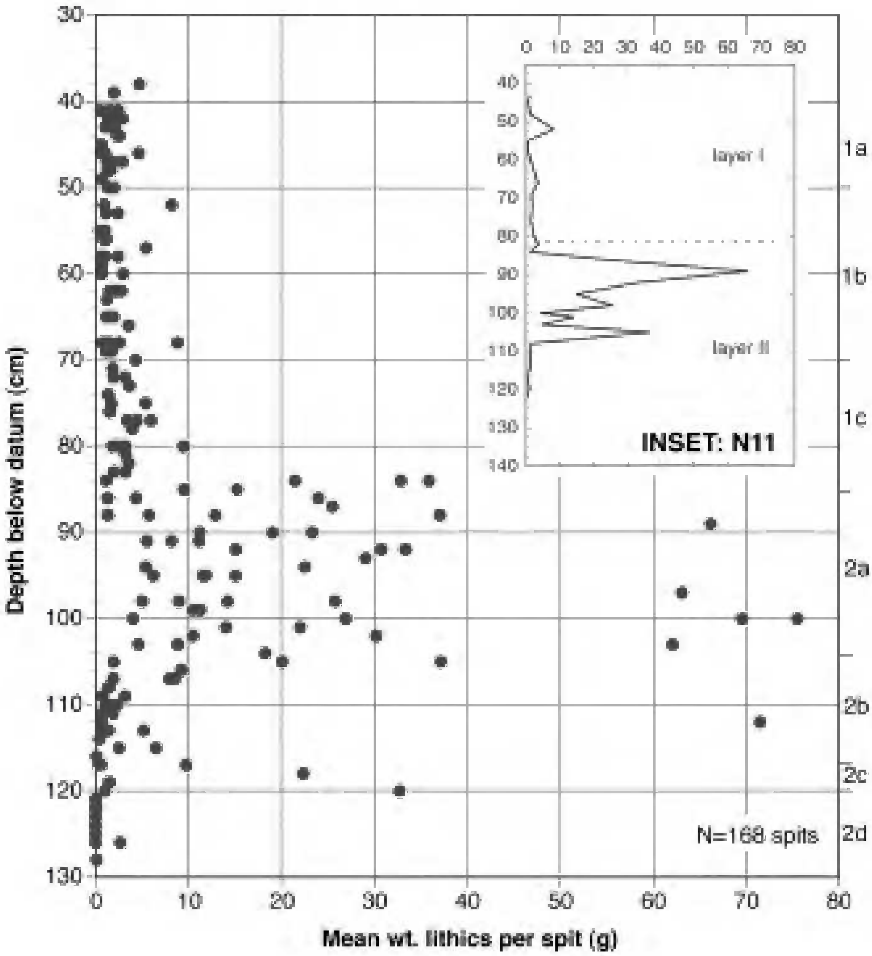


Fig. 14. Changes in the mean weight of artefacts over time, showing the concentration of large flake implements and large flakes in unit 2a (85–105 cm below datum). Plot shows data for the Main Trench, excluding doubtful artefacts from the lower part of 2d and intrusive pits or other features. Inset shows size trend in grid square N11. Data exclude N11/24-1, a large core (101 cm below datum) weighing 2119 g.

are smaller than those in 2a (mean wt.—1a and 1b:13±7 g, 2a: 60±29 g) but there is little difference in the length of working edge (mean retouch length mm—1a and 1b: 40±15 mm, 2a: 43±15 mm).

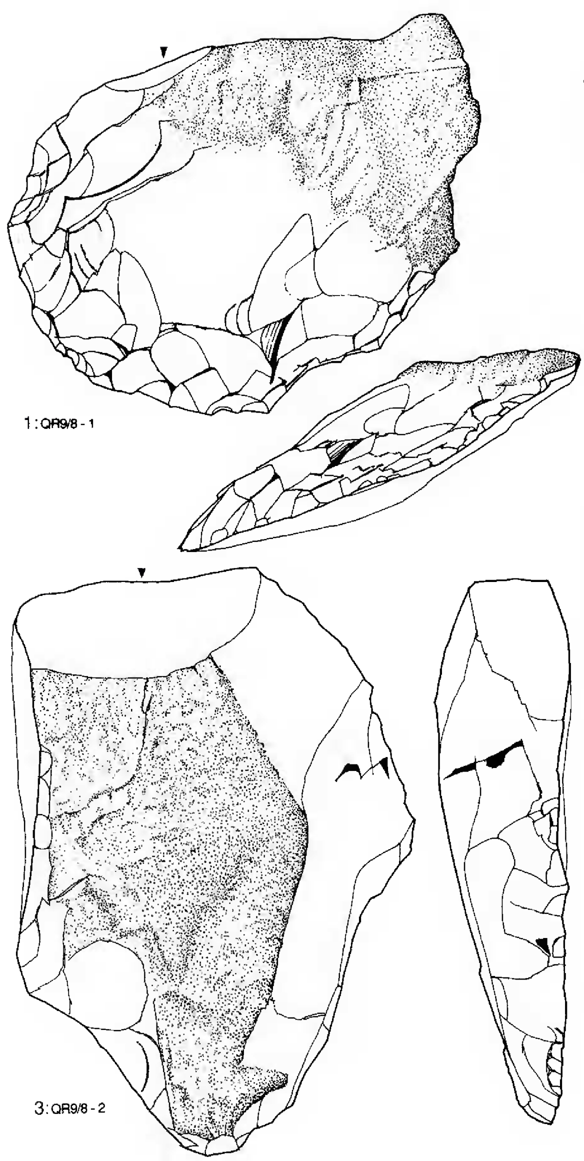
Other formal implements. QR9/8-1 (Fig. 15.1) has been carefully and deliberately worked and so warrants special mention. The blank is a large discoidal flake of silicified sandstone with a thick proximal end thinning out distally. This flake has been unifacially trimmed with shallow invasive flaking to a smooth convex edge with an edge angle c. 45°. The resulting edge is not sufficiently robust to sustain use as a scraper or chopper rather it seems best suited to working relatively soft materials with a slicing or cutting action. Microscopic examination of the edge for residues showed only soil starch to be present (see "Possible function of large implements" below).

Variability in Group 1 implements. Ethno-archaeological studies in the Australian desert have shown that—at least for edge-trimmed tools—a number of different morphologies could be used for the same function and that some of these forms simply represent episodes in the resharpening of an implement (Hayden, 1977—see also Hiscock, 1998 for a similar assessment). This is clearly a possibility with the Group 1 implements discussed here. Resharpening a thick serrated flake such as N10/9-1 (Fig. 16.9) could produce the steep concave working edges found on some steep-edged scrapers, such as N11/22-2 (Fig. 16.2), and further use could deepen this into a distinct notched edge resembling N13/20-1 (Fig. 16.6). However, at Puritjarra, the high variability within each class of implements makes formal statistical testing of these relationships difficult.

Group 2 implements

Group 2 artefacts (Fig. 18) represent a functionally heterogeneous suite of tools—spear armatures, adzes, and hafted scrapers—linked by a preference for chert and chalcedony and their function as elements of composite tools (as stone bits or barbs in multi-part implements made of wood, sinew and resin). Endscrapers are clearly an exception to this pattern as they are probably not components of composite tools: they may reflect specific ways of preparing tubers and fibrous roots rather than a new technology (O'Connell, 1974). At Puritjarra, Group 2 implements did not involve fundamental changes in flaking techniques: none of the new implements involved the production of blades or other specialized blanks (except perhaps tula adzes, which were not manufactured at the rock shelter). Rather, these technical developments appear to have centred around transformations of the wooden tool-kit associated with increased use of *Triodia* resin as a hafting cement.

Geometric microliths. These are small backed implements with abrupt blunting retouch along part or all of one side (cf. Holdaway & Stern, 2004: 262–264). Although not observed ethnographically, their use as barbs or armatures on spears is likely (see Kamminga, 1982; Mulvaney &



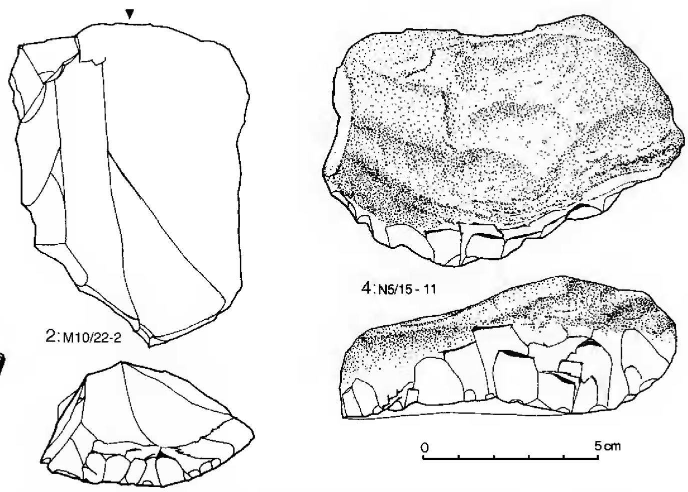


Fig. 15. Large flake implements from late Pleistocene levels of Puritjarra rock shelter. All are from unit 2a. Steep-edged scrapers: QR9/8-2, N5/15-11. Amorphous retouched implement: M10/22-2. QR9/8-1 is a large formal implement with extensive shallow invasive flaking and a thin convex working edge.

Kamminga, 1999: 235–236), although some may have served as small backed knifes, scrapers or incising tools. The geometric microliths at Puritjarra—like those elsewhere in Central Australia—are usually crescentic or triangular rather than trapezoidal in form and tend to be at the lower end of the size range for these implements (mean L 18±4 mm, B 10±2 mm, Th 4±1 mm, N = 38 complete specimens) (Fig. 18). Unlike sites in the Little Sandy Desert where backed asymmetric points are found (Veth, 1993: fig. 3.3), asymmetric forms are rare at Puritjarra and bondi points are not found. Microliths in unit 1a are slightly larger and squatter than those in 1b (mean L/B ratio, 1a: 1.8, 1b: 2.1) but the differences are probably not archaeologically significant. These implements are predominantly made on chert or chalcedony (79%) (N10/4-5, N9/3-4, Figs 18.2, 18.3) with the remainder on fine-grained grey silcrete (M10/6-1, M9/2-10, N6/5-2; Figs 18.1, 18.6, 18.8). The Puritjarra microliths are made on flakes rather than blades. This is generally the case in central Australia, though blades and blade cores occur in the late Holocene levels of some sites, such as Intirtekwerle, in the main ranges east of Puritjarra (Gould, 1978; Smith, 1988). One feature of the Puritjarra microliths is the number of unfinished (18%) or broken implements (19%). These probably represent failures during production, suggesting that microliths were manufactured at the site rather than simply brought in and discarded during repairs to spears.

Tula adze flakes and slugs. These are semi-discoidal implements with a pronounced bulb on the ventral surface and a convex cutting edge profile (cf. Holdaway & Stern, 2004: 253–256). Ethnographic studies show that these implements were mounted in a resin haft on a curved wooden handle and functioned as adzes for working desert hardwoods (Horne & Aiston, 1924; Roth, 1904; Spencer & Gillen, 1904). Experimental studies have shown that the morphology of the stone artefact both improves the function of the composite tool and prolongs the life of the hafting cement by reducing impact stresses (Sheridan, 1979). At Puritjarra, all the tulas are worn "slugs" (Fig. 18) except Z10/2-2 and M10/1-2 (not used because of a flaw in the edge of the tool). They are extremely variable in size, ranging from slugs on large flakes (M10/1-4) (breadth 47 mm) (Fig. 18.16) to very small slugs no larger than a thumbnail (N9/3-5) (breadth 17 mm). Most of the implements are on chert or chalcedony (88%) presumably because these materials hold an edge better than granular materials. Because heavy use and resharpening reduces the length of a tula relative to its breadth, the L/B ratio provides a rough measure of the condition of an implement. L/B ratios show that tulas in unit 1a (mean L/B 0.395) have marginally more wear than those in unit 1b (mean L/B 0.430). There is no evidence that adze flakes were manufactured at the rock shelter so the replacement of worn adzes must have involved blanks brought into the shelter from elsewhere.

Burren adzes. There are only five burren adzes in the excavated assemblage (e.g., Z9/9-2, Figs 18 and 19) (cf. Holdaway & Stern, 2004: 257). Their temporal distribution, raw materials and dimensions are similar to those recorded for tula slugs in the rock shelter. Therefore, they are probably best seen as a variant of tula use.

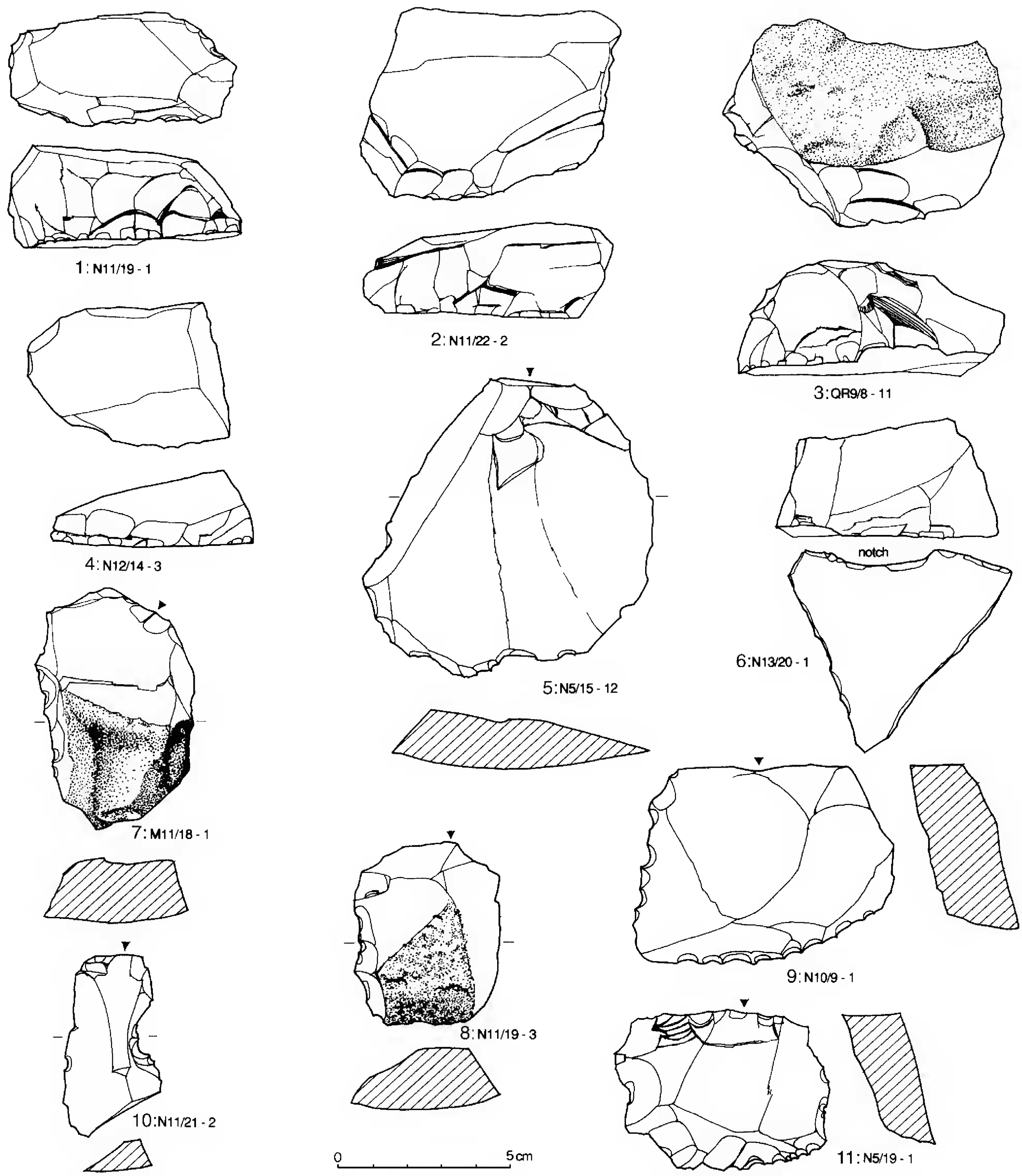


Fig. 16. Large flake implements from late Pleistocene levels of Puritjarra rock shelter. All are from unit 2a, except N13/20-1 (unit 2b). Steep-edged scrapers: N11/19-1, N11/22-2, QR9/8-11, N12/14-3. Amorphous retouched artefacts: N5/15-12, M11/18-1, N11/19-3. Notched implements: N13/20-1, N11/21-2. Saws: N10/9-1, N5/19-1.

Thumbnail scrapers. These are small discoidal scrapers, retouched to form a smooth convex edge on the distal margin (Figs 18.9 to 18.13) (cf. Holdaway & Stern, 2004: 234–235). They probably represent small, hafted scrapers. Like other Group 2 implements the thumbnails are mainly made on chert or chalcedony (73%) or on fine-grained silcrete. Some of the Puritjarra implements are large enough to have been serviceable as hand-held implements but many are too small to have functioned without some form of haft (mean L 15±3 mm, B 15±4 mm, Th 5±2 mm, N = 27 complete implements). Mulvaney & Kamminga (1999: 236) suggest that thumbnail scrapers were components of a spear armature ensemble. However, the pattern of wear on the Puritjarra implements is more consistent with woodworking or scraping fibrous materials: some thumbnails have steep step-flaked margins (M9/2-14) (Fig. 18.13), others have a polished rounded working edge with transverse striations (ST5/3-17, M9/2-13, N9/3-15). In Central Australia,

Table 12. Temporal distribution of flaked or ground tools and trimming flakes. Abbreviations: *I* and *II*—unassigned layers I and II.

artefact type	**analytical unit** 1a	1b	1c	*I*	2a	2b	2c	2d	*II*	total number of artefacts per type
Group 1										
Steep-edged scrapers	28	11	5	4	14	1	—	—	1	64
Notched implements	14	4	—	2	6	1	—	—	1	28
Saws	3	1	2	—	4	—	—	—	—	10
Other formal implements	—	—	—	—	1	—	—	—	—	1
Group 2										
Geometric microliths	29	17	1[e]	1	—	—	—	—	—	48
Tula adze flakes and slugs	23	10	—	1	—	—	—	—	—	34
Burren adzes	2	1	—	2	—	—	—	—	—	5
Thumbnail scrapers	23	6	—	1	—	—	—	—	—	30
Endscrapers	11	3	1[f]	2	—	—	—	—	—	17
Other retouched or utilized artefacts and trimming flakes										
Amorphous implements	121	60[h]	28	41	37	—	1	—	1	289
Fragments and trimming flakes	46	32	12	7	13	1	1	—	—	112
Redirecting flakes	19	7	10	5	4	1	—	—	—	46
Artefacts with use-polish	—[g]	—	—[g]	—[g]	2[g]	—	—	—	—	2
Grindstones[i]										
Seedgrinders	13	5	—	3	—	—	—	—	—	21
Amorphous grindstones	12	4	3	2	2	—	—	—	—	23
Grindstone fragments	24	2	5	12	2	—	—	1	—	46
Edge-ground tools										
Flakes from ground-edge axes	2	—	—	—	—	—	—	—	—	2
Hammerstones	—	—	—	—	2	—	—	—	—	2

[e] N6/15-1.
[f] M10/11-1, from the uppermost spit of 1c (see Figure 17-4).
[g] Indicates units where other retouched artefacts also have use-polish.
[h] Excludes N13/6-1, a glass artefact which is intrusive (see Table 4).
[i] Further details of the grindstones are given in Smith (2004).

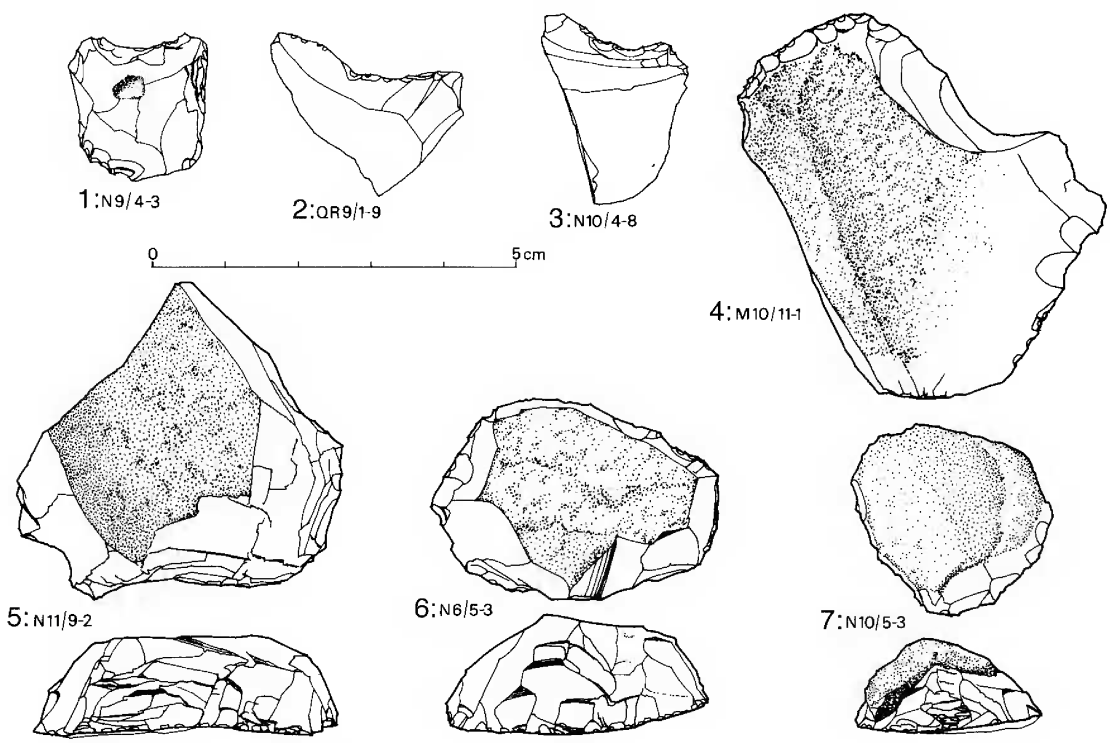


Fig. 17. Retouched artefacts from the Holocene levels of Puritjarra rock shelter. All are from units 1a and 1b except M10/11-1 (unit 1c). Steep-edged scrapers: N11/9-2, N6/5-3, N10/5-3. Notched implements: N9/4-3, QR9/1-9, N10/4-8. Endscraper: M10/11-1.

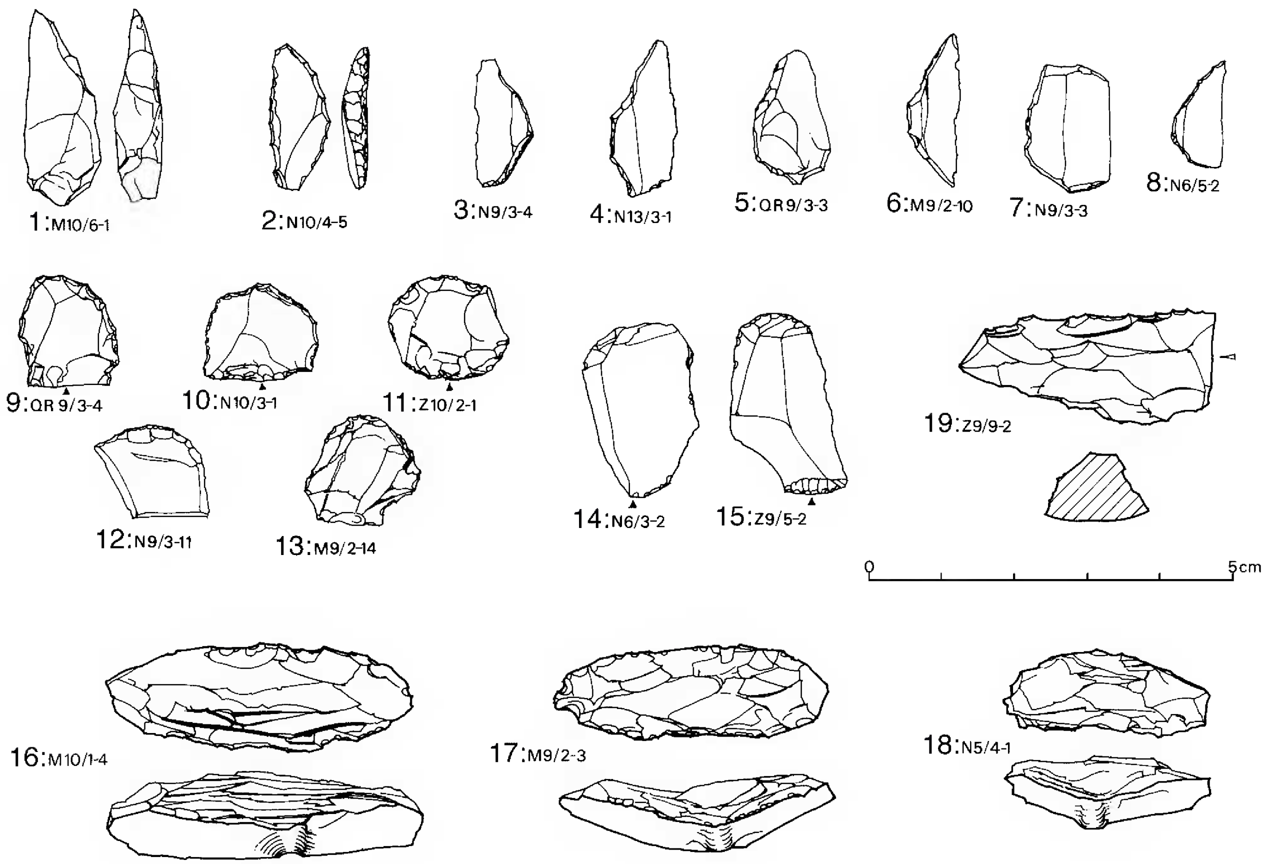


Fig. 18. Group 2 retouched artefacts from the Holocene levels of Puritjarra rock shelter. All are from units 1a and 1b. Geometric microliths: top row (1–8). Thumbnail scrapers: QR9/3-4, N10/3-1, Z10/2-1, N9/3-11, M9/2-14. Tula adze slugs: M10/1-4, M9/2-3, N5/4-1. (M10/1-4 is the largest tula in this assemblage). Burren adze slug: Z9/9-2. Endscrapers: N6/3-2, Z9/5-2. (Z9/5-2 has use-polish and rounding on the distal end, and fine overhang removal scars along the platform edge).

Table 13. Correlation matrix for tool types. Data are raw counts of each tool type per spit (excavation unit); n = 336 spits. This correlation matrix was generated as part of a Principal Components Analysis using the MV-ARCH program.

	Tula slugs	Thumb-nail scrapers	End-scrapers	Steep-edged scrapers	Notched tools	Saws	Amorphous retouched implements
Geometric microliths	0.38	0.32	0.24	0.13	0.04	-0.05	0.11
Tula adze slugs	—	0.27	0.24	0.17	0.18	-0.03	0.35
Thumbnail scrapers		—	0.21	0.09	0.03	-0.05	0.33
Endscrapers			—	0.13	-0.07	-0.08	0.09
Steep-edged scrapers				—	0.24	0.10	0.22
Notched tools					—	-0.05	0.21
Saws						—	-0.07
Amorphous retouched implements							—

thumbnail scrapers are best known from late Holocene assemblages, although these implements occur in late Pleistocene contexts in Tasmania (Holdaway, 2004).

Endscrapers. These are long flakes with a convex retouched edge on the distal end (cf. O'Connell, 1974, 1977: fig. 4g,h). Retouch ranges from finely invasive fluting to smooth step-flaking on the steeper edges. These implements are made on a variety of stone, but sandstone and silcrete were the most commonly used materials (71%). They may be a hand-held version of thumbnail scrapers. Like thumbnail scrapers, some endscrapers have a well-developed use-polish with striations running transverse to the edge (N6/3-2, Z9/5-2) (Figs 18.14, 18.15). Although their archaeological distribution is patchy, endscrapers have been recovered in excavations elsewhere in central Australia, at Puntutjarpa rock shelter (Gould, 1977: fig. 58) and Intirtekwerle (Gould, 1978: figs. 8c, 13; Smith, 1988: 230) and on open sites in the Sandover River region (O'Connell, 1977: fig. 4g,h). The function of these implements is not known but they may be a smaller version of the ethnographic implements known as "yilugwa" or "alywek" in Alyawarr, which were used as spoons and scrapers for preparing and consuming fibrous roots and tubers (O'Connell, 1974).

Table 14. Attributes of retouched artefacts. Data are for complete implements unless indicated.

Amorphous retouched implements

analytical unit	n	wt g	length mm	retouch L mm	l/b ratio[e]	>1 retouched edge %	% broken implements[f]
1a	103	16±34	31±16	25±15	1.3	12	15
1b	53	25±66	12	—	—	—	—
1c	24	30±36	—	14	—	—	—
2a	43	55±52	53±18	41±22	1.3	19	8
2b	0	—	—	—	—	—	—
2c	1	9	43	24	2.0	—	—

Steep-edged scrapers

analytical unit	n	wt g	length mm	retouch L mm	edge angle	>1 retouched edge	% broken implements[f]
1a	20	14±20	29±12	23±8	80	25	29
1b	10	18±17	31±8	28±11	77	20	9
1c	4	31±26	—	20	—	—	—
2a	14	136±204	64±35	43±32	71	57	—
2b	1	333	86	60	85	—	—

Notched implements

analytical unit	n	wt g	length mm	notch width mm	notch depth mm	>1 retouched edge[g]	% broken implements[f]
1a	14	7±6	29±10	11±5	2±1	29	—
1b	4	3±2	24±4	11±2	2±0	—	—
1c	—	—	—	—	—	—	—
2a	5	19±16	44±13	13±4	4±2	—	17

[e] Complete implements on flakes only.
[f] Artefacts where a section of retouch is truncated by a break. Calculated as percentage number of all of tools of this type in each unit.
[g] These artefacts have a retouched edge in addition to a notch. Only one implement has a second notch.

Temporal relationships of Group 2 implements. Although backed artefacts are known to occur in early Holocene contexts (Hiscock & Attenbrow, 1998), geometric microliths only make up a significant component of assemblages in south-eastern Australia after 4,000 B.P., spreading across the southern two thirds of the continent over the next millennium. At Puritjarra, the major distribution of geometric microliths, tula adze slugs and thumbnail scrapers is within the upper 25–30 cm of the deposit (units 1a and 1b, <3,500 B.P.) but neither are common until c. 2,000 B.P. A single small geometric microlith on chalcedony (weighing only 0.2 g) (N6/15-1) was recovered from the middle of unit 1c, where it would date to about 5,500 B.P. This conforms to the size and elongate form of the microliths in 1b. There is no sign of disturbance in this part of the site but, given its small size, the artefact may have been accidentally displaced from a higher level during excavation. Alternatively, microliths may have been occasionally produced in the mid Holocene.

Despite its long sequence, Puritjarra leaves the history of one of the most distinctive desert technologies unresolved. The combination of *Triodia* resin (as a hafting cement) with a specialized adze-morphology (the tula adze flake) is thought to be an adaptation specifically for working desert hardwoods (Sheridan, 1979). The earliest known tula slugs date to 3,500 B.P. at Devon Downs rock shelter in the lower Murray valley, and at the central Australian site of Kwerlpe, just above a radiocarbon date of 3,635±90 B.P. (I-7602) (Gould, 1978; Smith, 1988: 236). At Puritjarra, tula adzes appear abruptly in the sequence, with other Group 2 implements, without any indication of the history of development of these implements (the earliest examples are N5/7-5 and N5/7-6 from unit 1b which date to between 800 B.P. and 3,500 B.P.). A re-analysis of adzes from Puntutjarpa rock shelter in the Western Desert (Hiscock & Veth, 1991) came to similar conclusions, dismissing Gould's argument that there was a 10,000-year sequence for desert adzes at this site (Gould, 1977).

Regarding the origin of Group 2 implements, Hiscock (1994) argued that high-levels of residential mobility, and the need for a portable multi-functional tool-kit, underlay widespread use of these implements in the late Holocene. Whatever the case, the increased use of thermoplastics (such as *Triodia* resin) as hafting cement was the proximal cause of much of the variability in the late Holocene tool kit. First, it brought lithics into closer articulation with the wooden toolkit (as stone components or bits in wooden composite tools) where much of the functional variability in desert material culture is manifested (cf. Peterson, 1971). Secondly, we could expect new hafting methods to have a wide impact on a stone artefact assemblage (Keeley, 1982). At Puritjarra, we can see this not only in the appearance of Group 2 implements, but also in changes in the use and breakage of other implement types after 3,500 B.P., such as steep-edged scrapers and notched implements.

Other retouched or utilized artefacts

The common feature of the artefacts in this group is that they are products of the use and resharpening of implements.

Amorphous retouched artefacts. These are artefacts with a short length of retouch on one or more edges but with little modification of the overall form of the implement or the working edge. Most have evidence of only light trimming, resharpening or utilization. Few would be typologically classifiable as scrapers (only 9%, including M10/22-2, M11/18-1, N11/19-3) (Figs 15.2, 16.7, 16.8). The majority are made on flakes (84%). In units 1a and 1b these blanks were slightly thicker on average than unmodified flakes at the same level but are otherwise similar in size and shape. This is not the case in unit 2a where flakes >50 mm long were often selected for use as implements (e.g., M10/22-2, Fig. 15.2). As with other implement types, there is greater use of chert and chalcedony over time, as well as a progressive reduction in the size of these implements (Table 14). Breakage rates for artefacts in units 1a–c are also higher than those for unit 2a. Ethno-archaeological studies suggest that the major use of secondary retouch was to resharpen or rejuvenate a dulled working edge (Hayden, 1977: 179–180).

Retouched fragments and trimming flakes. Some of these artefacts are fragments of broken tools. Others, especially those in units 2a–c, are trimming or resharpening flakes off a retouched edge (M11/27-4, M11/23-7, N13/14-6). In units 2a–c materials such as grey silcrete and chalcedony are over-represented amongst trimming flakes, compared to implements. This suggests that tools of higher-grade stone were more extensively curated or recycled than those of local materials. Within the Holocene most of the artefacts in this category are broken ends or projections off retouched implements rather than trimming flakes.

Artefacts with use-polish. Throughout the Puritjarra assemblage there are a small number of artefacts with use-polish, fine abrasion and rounding of an edge (e.g., N13/18-16, N13/16-4). Sometimes this takes the form of a distinct bevel with striations transverse to the edge. It is often found on silcrete artefacts but is not restricted to one type of implement and is present on the chord of a geometric microlith (N9/3-3, Fig. 18.7), the edge of a tula slug (N11/2-3), on thumbnail scrapers, endscrapers, and on unretouched flakes. It is similar to the polish on ethnographic implements known as yilugwa, used as spoons and scrapers for fibrous roots and tubers (O'Connell, 1974).

Use and reduction of tools

Possible function of large implements in late glacial levels. The artefacts in unit 2a are extraordinarily large compared to those earlier in the late Pleistocene (units 2b–d), or in the mid-late Holocene (units 1a–c). Fig. 14 shows the extent of this trend, where the mean weight of lithics per spit in unit 2a (85–105 cm below datum) often falls in the range 10–40 g, in contrast to units 1a–c and 2b–d where mean weight of lithics per spit is generally less than 5.0 g. The implements in unit 2a contribute to this trend, with a mean weight of 75±127 g (unit 2a, all complete retouched artefacts, N = 62) compared to 13±34 g for units 1a–c (all complete retouched artefacts, N = 386).

Large flake or block implements, such as those found in unit 2a, probably served as expedient heavy-duty woodworking tools. However, microscopic examination of the edges of several tools for organic residues was inconclusive. Many flaked stone artefacts and grindstones at Puritjarra are covered with starch grains, especially acacia starch. This was also the case with the large flake implements examined (QR9/8-1, M10/22-2, N10/9-1) (Figs 15.1, 15.2, 16.9). Other work shows that starch occurs naturally in the rock shelter sediments (Bowdery, 1998; Smith, 2004: 179–180), often in appreciable quantities (>500 grains/mm^2 on non-cultural control samples), and may derive from deflation of inter-dunal soils beneath acacia groves upwind of the site.

The two functions which require a large artefact mass are heavy-duty woodworking (chopping or scraping) and use as a core. Artefacts identified as amorphous implements or saws are unlikely to be confused with cores. However, the question often arises as to whether steep-edged scrapers are cores rather than implements (Holdaway & Stern, 2004: 37–40, 204, 243–244). At Puritjarra these artefacts do not appear to reflect flake production. Most appear to be implements, since flaking is generally limited to their edges. Most flake scars are <10 mm long and the majority are shallow step-fractures suggestive of use damage rather than deliberate flake removals.

The ratio of unmodified flakes to cores offers some support for this interpretation (Table 15). Systematic misclassification of cores as tools would inflate flake/core ratios (by taking many cores out of the equation). However, flake/core ratios for unit 2a are very low compared to units 1a–c and 2b (the opposite of what we would expect if a significant number of cores were misclassified as tools). There are two alternative interpretations of this pattern: the steep-edged scrapers in 2a reflect repeated unsuccessful flaking or testing of sandstone blocks, or that blocks of stone were opportunistically used as implements and sometimes trimmed or resharpened during use. The latter seems more likely, especially given the other evidence for use of large flakes and large implements in unit 2a (Fig. 14).

Organic residues on chalcedony artefacts. Examination of artefacts for residues showed that chalcedony artefacts from unit 1a sometimes have a dark greasy film on their surfaces. The film on M11/3-5, a thumbnail scraper, was tested with hemastix and gave a strong positive (+++) reaction both with and without EDTA buffering, suggesting that this material is blood or animal grease. These residues do not appear to be restricted to a particular category of artefact, or to be limited to the edges of artefacts. Therefore,

Table 15. Flake:core ratios. Data are number of unmodified flakes relative to number of cores—for each raw material category.

analytical unit	all materials	silicified sand-stone	white chalcedony
1a	29	25	42
1b	38	39	33
1c	29	31	39
2a	11	8	13
2b	38	18	no cores

they may reflect the general context of use (spillage of blood and grease during food preparation nearby, greasy hands, etc.) rather than the primary function of these artefacts.

GIR and PRI for retouched flakes. Law (2003) has applied two reduction indices to retouched flakes in the Puritjarra assemblages (Table 16): the geometric index of reduction (GIR or GUIR) described by Kuhn (1990), and a perimeter reduction index (PRI) adapted from Barton (1988). GIR provides a measure of edge-thickness relative to flake-thickness, and interpolates the extent to which a lateral edge has been worked back towards the mid-line of the flake. Its major limitation is that it is only applicable to dorsally retouched flakes with a trigonal cross-section. The PRI is a simple measure of retouch length as a proportion of total edge-length on a complete flake. Although most of the samples in Law's study are too small (N <30) to reliably estimate population means and variance, several trends are suggested by his data. Flake tools are more heavily trimmed or resharpened in unit 1a and 1b compared to earlier levels, and this shift largely reflects more intensive reduction of stone from distant sources (50–100 km from Puritjarra) (Table 16a). Similarly, there is more extensive retouching of flake margins during unit 1a (Table 16b), and this also mainly involves stone from distant sources. Both trends are consistent with more intensive use of the rock shelter in the late Holocene, given that this is likely to have involved a greater range of on-site repair and maintenance tasks, as well as pressure to economize on the use of exotic stone by resharpening tools as much as possible (cf. Holdaway & Stern, 2004: 80).

Continuity and change in flaked stone industry

In archaeological nomenclature, a stone "industry" is a group of assemblages which reflect the operation of distinctive flaking or production methods, or are made on specific raw materials (e.g., quartz), or have a distinctive tool inventory (cf. Holdaway & Stern, 2004: 18). The premise is that a common technology will create similarities between assemblages irrespective of any variability created by local circumstances. In Europe and southern Africa, archaeological systematics provide much of the structure for regional prehistory. In Australia, where patterns of site use, mobility and logistics appear to be the major factors in inter-assemblage variability, it has been difficult to identify discrete stone industries (see Holdaway, 1995 for a discussion). In the Puritjarra sequence, there is little evidence to suggest that there was any significant change in flaked stone industry throughout the occupation of this site.

Flaking methods and core preparation. These remain broadly similar throughout occupation of the rock shelter, producing squarish flakes of variable size, from lightly prepared cores. The long-term trend towards smaller flakes and cores at this site, reflects more intensive core reduction, together with increasing use of cherts and chalcedony, rather than changes in flaking methods.

Shifts in raw material. The shift from silcrete-dominated assemblages in the late Pleistocene, to chert/chalcedony-dominated assemblages in the mid-late Holocene, appears to be a local rather than regional change. It is not evident at Kulpi Mara (Thorley, 1998b: 236) or at Puntutjarpa (Gould, 1977). Nor are chert and chalcedony invariably associated with small-tool phase assemblages in central Australia. The dominant raw material in late Holocene contexts is fine-grained silcrete (Gould, 1978; Smith, 1988). Of Group 2 implements, only tula adzes show strong preference for chert or chalcedony.

Changes in typology. These are limited to the late Holocene when small-tool phase (Group 2) implements appear in the Puritjarra sequence, about 3,000–3,500 B.P. (or possibly earlier if the geometric microlith in level 1c is accepted as in-situ), together with the earliest seed-grinders at this site (Smith, 2004). In the desert, Hamilton (1980) describes the ethnographic differentiation of tool kits into specialized men's (hafted

Table 16. Variation in flake retouch, after Law (2003, chapter 6).

	all materials		local stone		transported stone (50–100 km)	
analytical unit*	n	mean	n	mean	n	mean
(*a*) **Geometric index of flake reduction (GIR)**						
1a	55	0.42±0.18	19	0.34±0.11	18	0.46±0.21
1b	43	0.50±0.27	9	0.28±0.14	18	0.60±0.25
1c	15	0.39±0.14	11	0.40±0.15	3	0.32±0.12
2a	17	0.32±0.16	17	0.32±0.16	—	—
all units combined	130	0.43±0.21	56	0.34±0.14	39	0.51±0.24
(*b*) **Perimeter reduction index (PRI)**						
1a	132	0.41±0.21	47	0.33±0.18	50	0.43±0.21
1b	87	0.37±0.21	26	0.31±0.22	37	0.41±0.25
1c	29	0.37±0.18	20	0.38±0.19	8	0.37±0.12
2a	40	0.36±0.17	36	0.36±0.16	3	0.55±0.11
all units combined	288	0.38±0.20	129	0.34±0.18	98	0.42±0.18

* Law's study arbitrarily divides "unassigned layer I" material between units 1b and 1c and may obscure some differences between these units.

adzes and composite spears) and women's (seed grinding implements) equipment. If the appearance of Group 2 implements and seedgrinders can be taken as an archaeological correlate of this, it suggests that men's and women's roles became more strongly delineated after 3,500 B.P.

Earlier changes, towards the use of large flake and block implements in unit 2a, may reflect shifts in site function rather than typology, as these implements are found in lower frequencies throughout the late Pleistocene (unit 2b) and mid-Holocene (unit 1c) levels of the site. In this sense, the large core and flake artefacts in unit 2a would constitute a "facies" rather than an industry. Large block and flake artefacts have not been reported from terminal Pleistocene/early Holocene contexts elsewhere in central Australia—see Kulpi Mara (Thorley, 1998a,b); Puntutjarpa (Gould, 1977); and Serpent's Glen (O'Connor *et al.*, 1998)—but do occur at Hawker Lagoon and Balcoracana Creek in northern South Australia (Lampert & Hughes, 1988).

Characterising site use

We can work back from the economics of stone usage to reconstruct how sites such as Puritjarra articulated with a cultural landscape. Archaeologists, argues Binford, tend to see the past from the perspective of fixed positions in space. "The 'fallout' from the events that 'moved across' fixed places establishes the character of the archaeological remains on sites" (1982: 6). He suggests we image ourselves as observers at the bottom of a site "looking up as the dynamics of human systems pass over" (Binford, 1982: 20), emphasizing the potential to use sites like Puritjarra to provide a window on a wider cultural or economic landscape. Like similar studies (e.g., Cundy, 1990; Holdaway, 2004; Veth, 1993), the premise in this paper is that the strategies people adopted for acquiring, using and discarding stone, were embedded in a broader system of land use.

Table 17. Changes in intensity of occupation.

(*a*) Quantitative indicators

analytical unit	lithics no./10 kg[e]	cores no.	grind-stones no.	ochre no.	charcoal g/10 kg[e]	emu egg-shell wt. g	bone wt. g	pits and hearths no.
1a	48.6	34	49	33	5.21	12.6	62.6	10
1b	27.0	14	11	13	0.28	0.9	50.9	3
1c	14.0	11	8	29	0.01	—	2.0	3
2a	2.2	39	4	63	0.11	—	—	4
2b–d	<0.1	3	1	58	<0.01	—	—	—

[e] Relative to weight of excavated sediment.

(*b*) Estimated artefact discard rates

analytical unit	time period yrs B.P.	artefacts[f] no./100 yr	area excavated[g] %	estimated discard rates[h] no./100 yr
1a	0–800	903	3.5	25800
1b	800–3,500	201	3.3	6090
1c	3,500–7,500	59	3.3	1790
2a	7,500–18,000	17	3.0	570
2b–d	18,000–33,000	2	4.5	45

[f] Excavated trenches only.
[g] Of floor area available during each period.
[h] Interpolated for entire deposit.

(*c*) Other indices

analytical unit	reduction: retouched flakes (GIR)[i]	breakage rates: cores and tools %	breakage rates: flakes (L)[j] %	breakage rates: flakes (T)[k] %	tool inventory: richness[l]	tool inventory: diversity[m]	exotic materials: stone[n]	exotic materials: ochres[o]
1a	0.42	25	9	14	5.63	1.95	0.64	0.70
1b	0.50	31	8	22	4.80	1.74	0.67	0.62
1c	0.39	27	6	17	3.69	1.04	0.26	0.41
2a	0.32	18	6	2	4.19	1.32	0.26	0.59
2b–d	—	22	9	1	1.10	1.39	0.23	0.93

[i] Geometric Index of Reduction. Data from Law (2003).
[j] Longitudinal breaks.
[k] Transverse snaps or breaks.
[l] Richness is number of tool types/log(sample size).
[m] Shannon-Weaver diversity index (H) using data in Table 12, but excluding retouched fragments, trimming flakes and redirectors.
[n] Ratio by number of exotic:local stone, using data in Table 5. Exotic stone is stone from sources 50–100 km from Puritjarra.
[o] Ratio by number of exotic ochre (from sources 50–100 km from Puritjarra) to other ochres.

A wide range of indicators are commonly used to characterize the nature of occupation at a site: quantitative measures of occupation intensity including artefact discard rates; patterns of artefact breakage and recycling; indices of assemblage richness and diversity; flake reduction indices including GIR, PRI and flake/core or flake/tool ratios; and various proxy measures of residential mobility (for recent examples see Barton, 2003; Elston, 1990; Holdaway, 2000).

Tables 17 and, 19 summarize site use indicators for each analytical unit at Puritjarra. Some caveats need to be borne in mind in interpreting these indicators:

Behavioural correlates. Hiscock (1981) pointed out that general measures of "intensity of site usage" conflate different sorts of behaviour and that it is crucial to separate these during analysis.

Mix of occupation events. Analytical units will generally be a mix of different types of occupation event (each with a range of behaviours). Many occupation deposits represent palimpsests, involving a long-term process of accumulation, multiple occupation episodes, and a mix of short-term and extended-stay visits, with varying site inventories and patterns of residential mobility (cf. Barton, 2003). It follows that analytical units are unlikely to have direct analogues in ethnographic site types.

Shifts in archaeological signature. Binford reminds us that "humans may reposition their adaptive strategies in a landscape, a tactic which may generate variability in the archaeological record while serving to foster stability within the ongoing system" (1982: 6). Changes in the archaeological signature of a site (a composite of different types of occupation event) may reflect changes in the role of that site in a cultural landscape, rather than systemic changes in population, land use or subsistence.

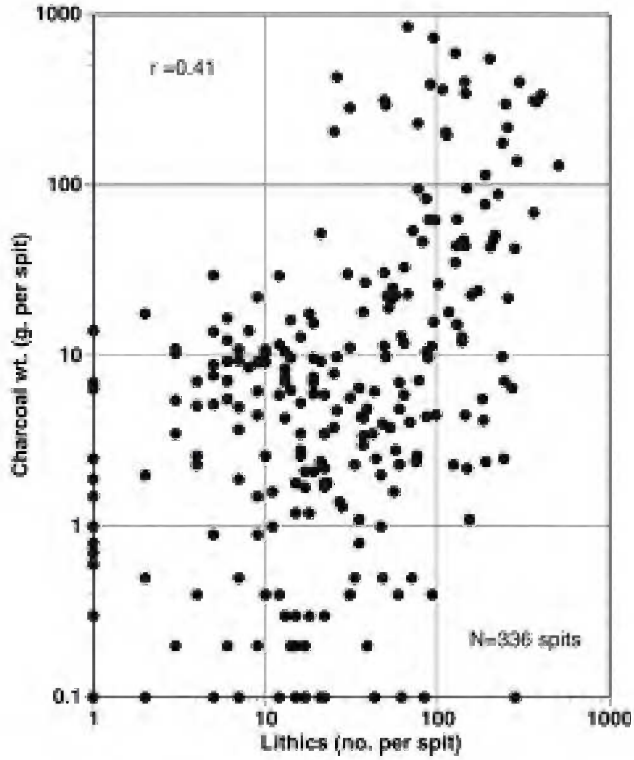


Fig. 19. Graph showing relationship between amount of charcoal and number of chipped stone artefacts in excavation units. Data are plotted for all spits (N=336). There is broad agreement between the two measures of occupational intensity (r=0.41).

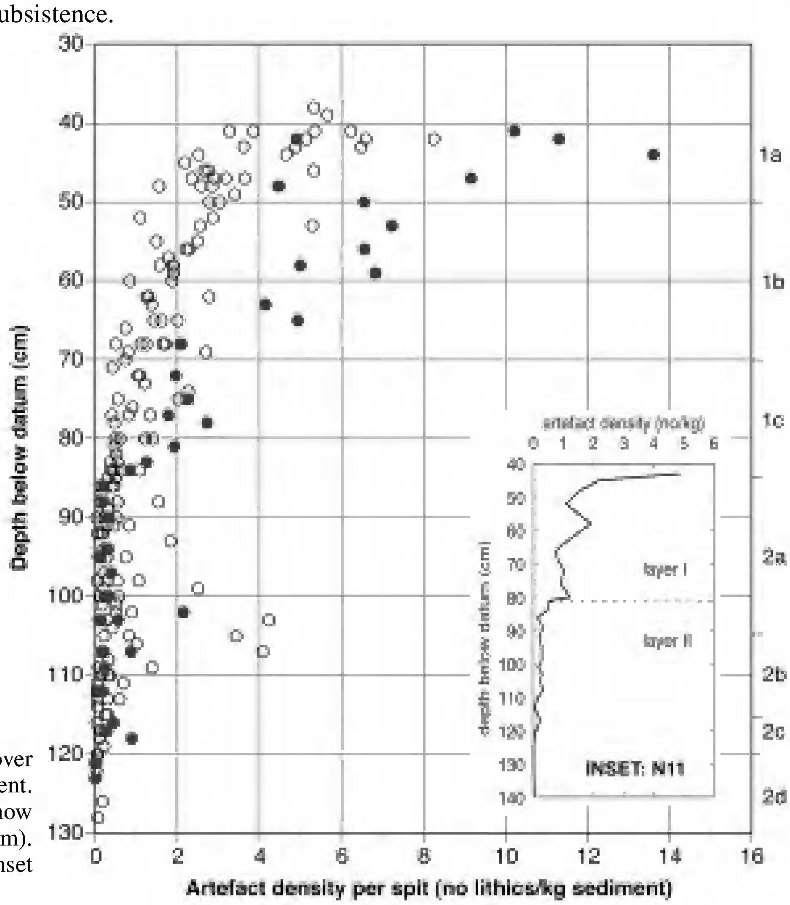


Fig. 20. Changes in the concentration of artefacts over time. Data are number of lithics per spit per kg sediment. Open circles are artefacts >6 mm. Solid circles show corresponding figures for fine flaking debitage (3-6mm). Plot shows data for the Main Trench (N=168 spits). Inset shows trend in grid square N11.

Table 18. Spatial distribution of artefacts.

analytical unit	rear wall N sector	rear wall rock fall zone	central floor N sector	central floor rock fall zone	central floor S sector	dripline
***(a)* Total number of artefacts**						
1a	541	121	4616	714	1111	124
1b and 1c[1]	983	1072	3930	537	1145	111
2a[2]	297	79	657	105	541	64
2b[3]	1	—	235	—	17	4
2c	—	—	41	—	—	1
2d[4]	—	—	16	—	—	—
***(b)* Frequency by unit (%)**						
1a	7	2	64	10	15	2
1b and 1c[1]	13	14	50	7	15	1
2a[2]	17	4	38	6	31	4
2b[3]	<1	—	91	—	7	1
2c	—	—	98	—	—	2
2d[4]	—	—	100	—	—	—
***(c)* Average weight (g)**						
1a	2.7	10.1	1.5	4.0	1.8	12.2
1b and 1c[1]	5.0	8.7	2.2	4.0	3.1	13.2
2a[2]	25.7	13.4	21.6	25.8	5.5	20.6
2b[3]	2.6	—	6.6	—	1.7	0.9
2c	—	—	5.9	—	—	0.8
2d[4]	—	—	2.5	—	—	—

1 Combined here with "unassigned layer I" to allow coverage of zones across the shelter floor.
2 Includes data from selected spits in "unassigned layer II": ST5/8-ST5/10, N10/7 and QR9/6.
3 Combined with remaining "unassigned layer II": N5/26, Z9/39 and Z10/9–Z10/10.
4 One core (M10/28-1) and five flakes (from N5/27, N11/35 and N12/31) are doubtful artefacts and are omitted.

Artefact deposition: densities and rates

The quantitative indicators in Table 17a show that Puritjarra rock shelter was used progressively more intensively over time—with the heaviest use of the site during the last 800 years (unit 1a). There is broad agreement between artefact discard rates (Table 17b) and changes in other occupational debris, such as the number of grindstones, frequency of pits and fireplaces, patterns of artefact breakage and reduction (Table 17c), and the concentration of charcoal in the deposit (Fig. 19).

Deposition of flaked stone artefacts was <0.5 artefacts/kg sediment throughout units 2a–d, increasing to 1.5 artefacts/kg in units 1b–c, and increasing again in unit 1a from 2.5 to >5 artefacts/kg (Fig. 20). The overall trend is towards higher concentrations of artefacts in the Holocene levels after c. 7,500 B.P. (Layer I) (80–82 cm). The distribution of fine flaking debitage (3–6 mm) shows a similar pattern to the larger artefacts (>6 mm) (Fig. 20) but concentrations of fine debitage are consistently higher than rates for larger artefacts. The two distributions begin to diverge in unit 1c as chert and chalcedony are more frequently used. In part, this reflects the higher visibility of these materials during sorting of the fine fraction.

Table 17b provides estimated artefact discard rates for each unit taking into account that the excavation trenches represent <5% of the floor area of the rock shelter. Hayden, who studied stone tool use amongst Pintupi people in the area immediately west of the Cleland Hills in 1971, calculated that a family in the Western Desert would use around 150±50 retouched artefacts per year and about the same number of unmodified flakes utilized as tools (Hayden, 1977: 273–274, see also Hayden, 1979: 165–166). Comparing these estimates with the Puritjarra assemblage suggests that unit 1a represents the long-term equivalent of use of the rock shelter by a nuclear family for about 3–6 weeks each year (based on 11–12 retouched artefacts/site/year). Such calculations are speculative, but seem the right order of magnitude given the duration for ethnographic camps in this region. Earlier levels must represent more ephemeral use of the rock shelter, but the diversification of tool-kits after 3,500 B.P. means that Hayden's figures cannot be directly applied to earlier assemblages.

Artefact concentrations are very variable during the late Pleistocene (2a–d) reflecting intermittent use of the rock shelter at this time. There is a localized concentration of artefacts at levels dated to the last glacial maximum (105 cm below datum) suggesting there was greater use of the rock shelter at this time (Figs 20 and 21).

Assemblage diversity and richness

Residential base-camps are locations where we could expect the widest of range of subsistence activities, tool production and repair, as well as extended residence—and hence the largest and most diverse artefact assemblages (Shott, 1986). On a multi-decadal timescale, repeated use of such central locations—involving long and short-stay visits, groups of varying composition, and occupation during different times of the year—is likely to reinforce a pattern of relatively dense

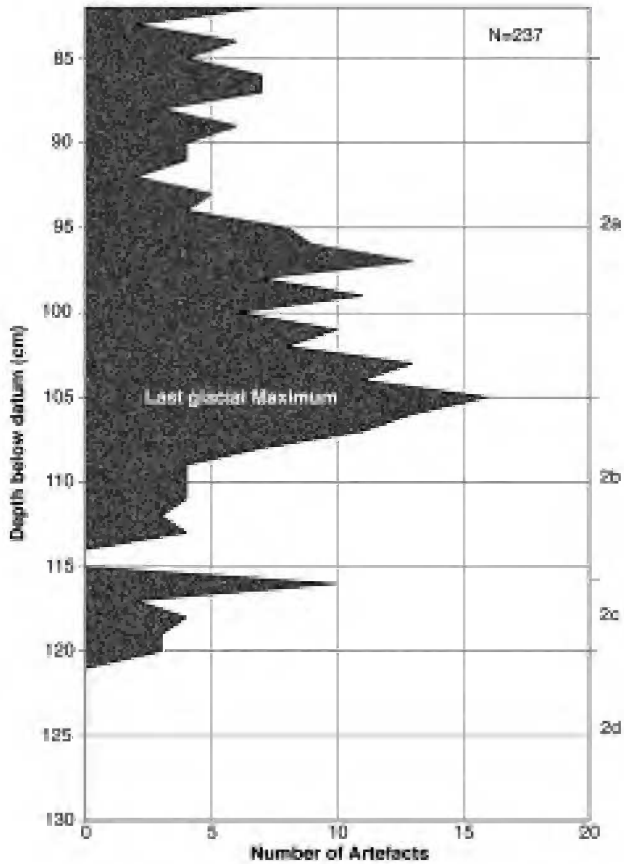


Fig. 21. Fine-grained vertical distribution of artefacts in late Pleistocene sediments (units 2a–d). Data are number of levelled finds (artefacts for which the precise depth was recorded in-situ during excavation) per cm depth in the Main Trench. The plot shows the concentration of artefacts on the palaeosurface at c. 32000 B.P., and a peak in artefact numbers coinciding with the last glacial maximum.

and coarse-grained assemblages (as Veth, 1993: 82 found for core occupation sites near water in the Great Sandy Desert).

Table 17c gives estimates of assemblage diversity and richness for the Puritjarra occupations. Following Odum (1971: 144), *richness* is number of tool types/log (sample size), and *diversity* is the Shannon-Weaver diversity index (H') (Odum, 1971: 144). Richness is standardized against log(sample size) to remove the effect of sample size on number of tool types. The results in Table 17c show that site inventories (richness) increase over time, with unit 1a being noticeably richer than other units. Similarly, diversity increases over time, and unit 1a has the most diverse assemblage. Both indices identify unit 1c as an anomaly in this trend, with a more limited site inventory.

Barton (2003: table 5) includes comparative data for open sites in the Simpson Desert. Values for unit 1a are comparable to those for residential base camps, near springs in the Simpson Desert (richness 5.44; diversity 1.58). Site inventories in units 2b–d are conspicuously poorer than anything in Barton's sample. Veth (2005a: table 6.6) provides figures for artefact diversity on Western Desert sites (8.0 for base camps; 4.0 for ephemeral residential camps; 2.0 for task specific sites). These figures are higher than in any unit at Puritjarra, but may not be strictly comparable: That they are so much higher than those in the Simpson Desert sample, may indicate he has used a different algorithm to calculate "diversity".

Breakage patterns

Transverse snapping of flakes is generally taken as an indicator of the intensity of treadage on a surface, prior to burial of the flakes (Holdaway & Stern, 2004: 114). Longitudinal breaks or splits in flakes tend to derive from problems during knapping. At Puritjarra, the higher incidence of transverse breaks in layer I (units 1a–c) (Table 17c), despite the higher rate of sediment accumulation in this layer, indicates more intensive use of the rock shelter after 7,500 B.P. Breakage patterns for tools and cores (Table 17c) show a similar pattern (though these indicate breakage during use). The incidence of longitudinal breaks shows less variability—much as we might expect, given there is little change in flaking methods during the history of the shelter.

Spatial patterns

Spatial patterns in archaeological remains at different levels confirm the picture of progressively more intensive use of the rock shelter over time. People using a campsite for any length of time tend to clear living surfaces and heavily trafficked areas of large debris. Larger items often end up on talus slopes outside a rock shelter or along the drip-line at the edge of the overhang. At Puritjarra, the general pattern was that larger rocks and artefacts were discarded along the drip-line and also around the large boulders that divide the central area of the rock shelter floor into northern and southern sectors (Table 18). Artefacts left on the main living floor average only a few grams. This pattern was not established until c. 7,500 B.P., coinciding with other evidence for more intensive use of the shelter during the mid-late Holocene (units 1a–c).

When people first used Puritjarra, the major rock-free floor was the northern sector of the shelter. Occupation of the rock shelter at the time units 2b and 2c were accumulating was limited to the central part of this floor and most artefacts appear to have been left where they were used or produced.

During unit 2a occupation extended across all zones of the rock shelter, from the rear wall out to the drip-line, and included both northern and southern sectors of the floor. At least one hearth in the central of the floor is associated with this horizon (dated by M10/20-4, 9,110±120 B.P. ANU 6538). Towards the rear wall a small pit (N5/25) was dug about 13,000 B.P. and rapidly filled with sediment leaving a shallow depression in which debris of various sorts subsequently accumulated, including cores, large flake implements and a large tablet of red ochre. However, there was little size sorting of debris at this time, except perhaps on the southern floor: large artefacts were usually left on living surfaces. This indicates that most visits were still relatively short.

The modern pattern was established during unit 1c: larger debris was routinely cleared from the central floor of the rock shelter. Larger rocks, cores and broken grindstones accumulated around fallen boulders and between these boulders and the rear wall of the rock shelter. A range of pits and fireplaces are associated with unit 1a, and intact grinding slabs are sometimes associated with small ashy lenses in this unit.

Mobility indicators

Changes in intensity of site usage can be broken down into a number of components: changes in group size; changes in the duration of visits; or changes in the frequency of visits. Behr (1990) and Law (2003) have attempted to "unpack" the trend towards more intensive use of Puritjarra rock shelter during the last millennium. Both studies suggested that increased residential mobility was involved in this shift (i.e. more frequent visits to the rock shelter), based on increased use of white chalcedony at this time.

Table 19 gives various measures of relative mobility for the Puritjarra assemblages. The premise underlying such indicators is that highly mobile groups generate assemblages with the highest proportion of exotic raw materials, but only small numbers of tools, whereas less mobile groups make greater use of local stone, more intensively use and recycle any exotic stone available, and generate more diverse site inventories (see Holdaway & Stern, 2004: 80 for a discussion).

At Puritjarra, the most diverse tool inventories and greatest reduction of white chalcedony occur in unit 1a. This unit also has the lowest flake/tool ratio, indicating that a relatively high proportion of chalcedony flakes have been transformed into tools (complementing GIR and PRI indices showing greater resharpening of chalcedony flakes in this unit). High flake/core ratios can indicate either (a) greater reduction of cores, or (b) their systematic removal from the site by mobile groups (cf. Holdaway, 2000: 223). At Puritjarra, the evidence is more consistent with increasing reduction of cores, together with a trend towards a reduction in chalcedony flake length over time (though this is not statistically significant), and an overall reduction in the weight of white chalcedony artefacts. These indicators point to extended occupation of the rock shelter in unit 1a, confirming the pattern shown by artefact discard rates and changes in other occupational debris.

Against this trend, the high proportion of exotic stone and ochre in unit 1a is an anomaly. It could reflect a switch in provisioning strategy, from "embedded" procurement of stone and ochre (Holdaway & Stern, 2004: 80) to a logistical pattern of direct procurement, as use of the rock shelter intensified. However, I think it more likely that unit 1a is a mix of extended and short-term occupations involving more frequent cycling of people through the shelter. Veth (1993) describes a "dual" system of seasonally occupied core occupation sites and satellite camps for the Martutjara in the Great Sandy Desert. It is relevant that residential base camps in the Great Sandy Desert also have high frequencies of non-local stone (62%) (Veth, 1993: table 4.2), combining this with heavy reduction of exotic stone.

Table 19 ranks analytical units against each mobility indicator, and sums rank-order scores to produce an index of relative mobility. The results show a decline in overall residential mobility over time—irrespective of any changes in the "mix" of occupations in these units.

Discussion

History of the rock shelter

The archaeological evidence suggests a series of phase shifts in the character of occupation at Puritjarra. Although each of these phases must represent a palimpsest of numerous small camps and a mix of debris from different tasks, functions and activities, the cumulative archaeological signature is different in each phase. The pattern of occupation in units 1c, 2a and 2b–c could be seen as variants of the one system—scaled by task and intensity of residential mobility—but even here the changes are sustained and probably represent significant restructuring of land use in the Cleland Hills. The following discussion draws together the various lines of evidence about the nature of occupation in each phase.

Initial visits to the rock shelter

Colonization of the Australian desert may well have been preceded by an exploratory or pioneer phase, involving the dispersal of human groups across the interior (see Smith, 2005b for a discussion). Given that human dispersal across the continent took place before 45,000 years ago (O'Connell & Allen, 2004) and that the northern margins of the desert were settled soon after, we could expect the first movements into the desert in the period 35,000–45,000 years ago, though there is no firm evidence for this at present. At Puritjarra, however, there is some *equivocal* evidence for fleeting human visits prior to occupation at c. 32,000 B.P. (unit 2c). Excavations at the base of layer II (the lower part of unit 2d), recovered a small number of artefacts and possible artefacts in sediments dating to 44.8±3.6 ka (AdTL91010). These include 5 small flakes (an ironstone flake N5/27-1, plus 3 grey silcrete flakes from N11/35 and 1 from N12/31), a large sandstone block with flake scars along both sides of one edge that may be a core (M10/28-1), and a small piece of fine red ochre (0.59 g) from N12/

Table 19. Index of relative mobility. Data are for artefacts on white chalcedony only, except where indicated otherwise. Figures in brackets give rank order by variable.

analytical unit	diversity[e]	flake:tool ratio[f]	flake:core ratio	mean weight lithics (g)	exotic stone[g]	exotic ochre[h]	rank sum	relative mobility[i]
1a	1.95 (1)	1.85 (2)	42 (1)	0.70 (1)	0.64 (3)	0.70 (4)	12	1
1b	1.74 (2)	1.88 (1)	33 (3)	0.72 (2)	0.67 (4)	0.62 (3)	15	2
1c	1.04 (5)	2.79 (4)	39 (2)	0.84 (3)	0.26 (2)	0.41 (1)	17	3
2a	1.32 (4)	2.78 (3)	13 (4)	2.44 (5)	0.26 (2)	0.59 (2)	20	4
2b–d	1.39 (3)	3.00 (5)	no cores (5)	1.55 (4)	0.23 (1)	0.93 (5)	23	5

[e] All raw materials—from Table 17c.
[f] Tools on flake blanks only.
[g] Ratio of exotic:local stone—from Table 17c. Exotic stone includes chalcedony, chert and silcrete.
[h] Ratio of exotic:other ochres—from Table 17c.
[i] Higher values indicate greater mobility.

33. Of these, the ironstone flake and possible core are on local stone and could therefore be chance products of roof-fall. The four silcrete flakes and piece of ochre are related to human activity, but may not be in-situ, as I could find no corroborative evidence of occupation at this level (such as fine flaking debitage or charcoal). It remains a possibility that people visited Puritjarra prior to c. 32,000 B.P., but existing evidence is insufficient to decide the issue one way or another.

Late Pleistocene occupation (units 2b–d)

A pattern of use of the rock shelter was not established until c. 32,000 B.P. (approximately 35,000–36,000 years cal. B.P.), when increasing aridity may have contributed to greater use of sites like Puritjarra (and hence greater archaeological visibility). The first indication of this is a small scatter of silcrete and chalcedony flakes in the upper part of 2d directly beneath the palaeosurface that represents unit 2c. The excavation suggests a pattern of small shifting scatters of artefacts and occupation debris in the central part of the floor at the northern end of the rock shelter. Unit 2c has the most clearly defined of these scatters (Figs 14 and 21) perhaps because there were few artefacts deposited immediately above it. Note that the gap in occupation that can be seen in Fig. 21 is a shift in location within the rock shelter rather than a break in occupation: fine debitage and a small number of artefacts were recovered from the sieves from this level (see also Smith, 1989: fig. 5 and discussion—but note the chronology has been revised). The pattern established in unit 2c—short visits to the rock shelter by small, highly mobile groups—continued throughout unit 2b.

People visiting the rock shelter during the accumulation of units 2b–c were moving over a wide territory lying west of the main central Australian ranges: they acquired red ochre from the Karrku mine, 125 km north west of Puritjarra (Smith *et al.*, 1998) and brought in flakes of fine-grained silcrete probably from the western end of the main range system, and pieces of white chalcedony. They used steep-edged scrapers made of local sandstone but also fine retouched convex scrapers made of grey silcrete from sources in the Cleland Hills. The latter are only represented by the flakes removed from their edges when they were resharpened: these implements appear to have been strongly curated. The paucity of broken tools or cores and the absence of evidence for clearing debris from occupation surfaces suggest that use of the rock shelter was transitory. In particular, in unit 2c the high proportion of artefacts made of exotic silcrete and chalcedony and the relatively low use of local silicified sandstone indicate greater residential mobility than at any other time in the history of the rock shelter.

The last glacial maximum

Research into the chronology and environmental history of layer II over the last 10 years (Bowdery, 1995, 1998; Smith *et al.*, 1997) has more precisely identified the levels which correspond to the last glacial maximum at this site. The trend of the radiocarbon series indicates that a level 105 cm below datum corresponds to the peak of the last glacial maximum. This is directly dated by ANU 6918 (17,980±160 B.P., recently re-dated using ABOX AMS ^{14}C as 20,240±280 B.P., ANUA10010) (Smith *et al.*, 2001), and is cross-referenced to a major decline in shrubs and grasses in the phytolith sequence at this level (Bowdery, 1998), indicating greater aridity at this time.

A peak in the number of artefacts recorded *in-situ* during excavation, coincides with the LGM levels (Fig. 21), suggesting a greater focus at this time on sites near major waterholes. Closer analysis shows that at 105±2 or between 103–107 cm below datum (63–67 cm below surface) there are 145 artefacts: five retouched artefacts, 40 flakes, three cores and 97 pieces of debitage. The three cores include an amorphous core (N13/20-4, 71.4 g) and two platform cores (N13/20-3, 144.2g; M11/24-1, 2112.3 g) all of silicified sandstone. The retouched artefacts include a notched implement (N13/20-1, Fig. 16.6), three amorphous retouched tools (M11/23-2, N11/26-2 and M10/22-2, Fig. 15.2), and a trimming flake removed from the finely retouched edge of a silcrete tool (M11/23-7). The flakes include small flakes of chert and silcrete and large flakes of local silicified sandstone.

These levels also show the greatest reliance on local silicified sandstone of any of the excavated levels (Table 5). Small pieces of red ochre from these levels are sourced to the Karrku ochre mine to the north, and the artefacts include flakes of exotic silcrete ("Other silcrete" in Table 4). This pattern suggests people were still using a wide territory, but were now combining this with occasional extended visits to sites near reliable waters, such as Puritjarra.

Given that resolution of the Pleistocene record at Puritjarra is ±200 years at best, or more realistically ±500 years, there are obvious limits in our ability to identify gaps in occupation of the shelter itself. However, the fact that there is continuity in implement types and flake technology, and in the sources of stone and red ochre reaching the rock shelter across this period, suggests the LGM did not cause any prolonged hiatus in occupation of the region. The main impact appears to have been on the pattern of land use: at Puritjarra, the LGM coincides with the switch from unit 2b to 2a, reflecting a shift in the role of this rock shelter, rather than a change in stone industry.

Thorley (1998a: 43) was understandably sceptical about evidence for use of the shelter during the LGM, commenting that the small number of artefacts in these deposits could have been displaced from younger levels. He pointed out that sporadic, light occupation is contrary to what would be expected for a site near permanent water at this time. Much of this critique was misplaced as it did not take into account revisions to the chronology of the late Pleistocene deposits (Bowdery, 1995; Smith *et al.*, 1997) since the initial reports of the 1980s. These provide a much stronger picture of water-tethered occupation during the LGM.

The terminal Pleistocene (unit 2a)

The most striking change in unit 2a—and the feature that gives this horizon some stratigraphic definition—is the greater emphasis on use of large core or flake tools (mainly steep-edged scrapers, notched implements and amorphous retouched tools) as well as large unmodified flakes. These artefacts are not exclusively on local silicified sandstone: large flakes of chert and silcrete were also brought to the site, though not manufactured on-site. The large implements suggest greater emphasis on heavy-duty woodworking. We can only speculate on the significance of this change. There may have been a more elaborate suite of wooden implements at this time, greater need for the repair and replacement of such items, or perhaps it became increasingly important to "gear up" at sites near permanent water, such as nearby Murantji rock hole. Whatever the explanation, the last glacial maximum appears to have triggered a new pattern of site use.

From c. 12,000–13,000 B.P., a series of changes suggest a switch to a more geographically circumscribed population using local range and dune country in the vicinity of the Cleland Hills. Within unit 2a, there is a band of large implements at c. 12,000–13,000 B.P. (95–98 cm below datum). The lithic assemblage from this part of unit 2a is larger and comparatively richer than that in earlier levels, the first pits or hearths appear, and these levels include the earliest grindstones. Camps were larger, as occupation debris now extended across most parts of the rock shelter floor, but must still have been of short duration as there was no attempt to clear large debris from occupation surfaces and other heavily trafficked areas.

Residential mobility remained high, but site territory (or site catchment) may been more limited. Excavated ochres show greater use of local sources and of ochre from Ulpunyali, the closest of the major ochre quarries to Puritjarra (50 km south east of the rock shelter). An earlier study of the ochres (Smith *et al.*, 1998) used a preliminary age estimate of 13,000 B.P. for the base of unit 2a. The revised chronology used here makes little difference to the conclusions of that study: Table 20 provides a breakdown of ochres by source within unit 2a, showing that the major changes in ochre provenance date to c. 12,000–13,000 B.P. rather than the base of 2a. The concentration of ochre near the rock shelter wall, suggests production of rock paintings from 13,000 B.P., though none of this pigment art survives today. Pecked engravings on boulders embedded in the floor of the shelter probably also date from this time period. Both paintings and engravings may signal a concern to more visibly assert rights and relationships to the site.

Table 20. Distribution of ochre in unit 2a. Data are number of pieces in each category.

analytical unit	depth below datum	group 1 (Karrku)	group 2 (Ulpunyali)	other ochres
2a	85–90 cm	—	—	—
2a	90–98 cm*	19 (36%)	12 (23%)	22 (41%)
2a	98–105 cm	6 (60%)	—	4 (40%)

* Levels dating between 10,500 B.P. and 12,000–13,000 B.P.

The mid Holocene (unit 1c)

After c. 7,500 B.P. people began to use the rock shelter more intensively, coinciding with the onset of conditions sufficiently humid to alter patterns of sedimentation and weathering in the rock shelter. There is a significant increase in artefact discard rates, more broken tools and broken cores, and both implements and cores are more heavily worked. Larger debris was cleared from the floor of the rock shelter, reflecting extended episodes of occupation. Grindstones become more common indicating greater use of plant processing gear. There was more use of locally available ochres and a greater reliance on local sandstone for artefacts. Except for white chalcedony, the use of non-local stone sources declines or remains low. Exotic silcrete virtually disappears from the sequence.

All this points to more local provisioning and visits to the rock shelter that on average were more sustained, not simply more frequent—and site territories that remained as restricted in extent as those at the time unit 2a accumulated. In many respects, unit 1c occupation continues trends in site use initiated around 13,000 B.P. in unit 2a.

Late Holocene occupation (units 1a–b)

From 3,500 B.P., the people visiting Puritjarra were using a more diverse tool kit, including hafted adzes and scrapers and other composite artefacts of wood, resin and stone—as well as specialized seed grinding implements for processing grass and acacia seeds. Unit 1b records increasing use of the rock shelter, with relatively high levels of breakage of cores and tools, of treadage and trampling, and of artefact reduction. The large increase in exotic stone and ochre in 1b signals a significant broadening of site catchment, reflecting either a shift in the way these materials were acquired (i.e. a shift to logistical procurement; or stronger social exchange networks), or a more complex mix of extended and short-term occupation during the accumulation of this unit.

There was a further substantial increase in use of the rock shelter around 800 B.P. (unit 1a). This involved a large increase in artefact discard rates, more pits and fireplaces, more ochre (especially from the Karrku mine), more grindstones (especially seed grinding implements which are more numerous in 1a than any other level) and the richest and most diverse tool inventory recorded at this site. By 800 B.P. Puritjarra was a core residential site with extended periods of occupation, and probably one of a number of such sites in the Cleland Hills. This shift may be underpinned by changes in regional environments as phytolith records at Puritjarra show that, during the last 1000–1500 years, grass levels stabilized at their highest values since the last interglacial, indicating greatly improved summer rainfall. Continuing the trend begun in unit 1b, occupation during the last 800 years may also have involved a dual pattern, with a marked seasonal component, frequent shorter visits, and frequent cycling of people through the site—intercalated with a pattern of extended episodes of occupation.

Implications

The Puritjarra sequence has implications for ideas about prehistoric land use in the Australian desert, though comparable data from other excavated sites is urgently required to establish the variability and extent of internal differentiation in these systems.

The nature of late Pleistocene occupation. Detailed analysis of the Puritjarra assemblages supports the notion that late Pleistocene groups in the Australian desert were small, highly mobile groups using large territories. In many respects, the archaeological pattern between 32,000–18,000 B.P. resembles an extreme form of the ethnographic pattern in the Western Desert: small groups, low population density, high residential mobility, and generalized foraging (i.e. residential mobility was high throughout the period of occupation at Puritjarra, but was more extreme in this earlier period). However, Puritjarra also shows there was considerable variability in late Pleistocene site patterns and assemblages, particularly between pre- and postglacial occupations. The postglacial levels of Puritjarra show evidence for larger, more geographically circumscribed groups using the rock shelter in the terminal Pleistocene and early Holocene, especially around 12,000–13,000 B.P.

Impact of the last glacial maximum. Puritjarra registers the impact of the heightened aridity around 18,000–20,000 B.P. on residential mobility and site territory, with an apparent shift to a pattern of more focussed or "water-tethered" occupation during the LGM. Populations appear to have persisted in western central Australia throughout this period (see similar evidence from Yirra rock shelter in the Pilbara, Veitch *et al*., 2005). Continuities in tool inventories, stone technology, and in the sources of stone or red ochre reaching Puritjarra, suggest that any disruption to use of the rock shelter is more likely to reflect inter-decadal variability in regional environments than regional abandonment.

System response to environmental change. The pattern of phase shifts in occupation at Puritjarra suggests that models of *metastable equilibrium* have a role in understanding changes in land use in the arid zone. Metastable equilibrium is "where a specific catalyst or trigger carries a system over a threshold into a new equilibrium state" (Frankel, 1988: 41). The Puritjarra sequence suggests that sharp environmental transitions, such as those at 18,000 B.P. and 7,500 B.P., destabilized local patterns of land use and led to a re-positioning of cultural activities in the landscape. The new pattern was comparatively stable despite ongoing changes in regional environments, at least until the next major environmental spike. A similar response may help explain why the Western Desert site of Serpent's Glen, apparently abandoned around 24,000 B.P. as aridity increased, remained unoccupied until the mid Holocene at 4,700 B.P.

Late Holocene shifts in mobility patterns. At Puritjarra, evidence for a shift to a more mobile pattern of land use after 3,500 B.P. is equivocal at best. Any changes in group mobility in the late Holocene appear to have occurred within the context of more intensive occupation of the rock shelter. It is possible that a "home-range" pattern of seasonal or inter-annual movement would have increased the frequency of shorter visits to central places, such as Puritjarra, in between episodes of more extended use. However, other mechanisms—such as changes towards direct provisioning of stone and ochre as use of the shelter intensified, or more effective social exchange networks as regional population increased—may also account for the observed pattern. At Puritjarra, the last millennium sharpened this "dual" pattern, combining more intensive use of the rock shelter with the discard of larger quantities of exotic stone and ochre.

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Appendix 1—Definitions of attributes

Stone artefact attributes used in this study follow definitions in Andrefsky (1998), Cotterell & Kamminga (1987), Holdaway & Stern (2004) and Hiscock (1986: 48–49). All metrical attributes were measured to the nearest mm.

Weight. Mass, measured to the nearest 0.1g but rounded to the nearest gram.

Length. For flakes, length is the maximum dimension parallel to the percussion axis (Andrefsky, 1998: fig. 5.8c). Where the percussion axis could not be determined, length was the maximum dimension of the artefact. For geometric microliths, where orientation of the artefact relative to the worked margin is important, it is the length of the edge opposite the backed margin.

Retouch length. Length of the longest contiguous section of retouch on an artefact.

Core height. Core height is the maximum dimension of a core taken at 90° to the major platform. Effectively it is core length. For discoidal or bifacial cores it is maximum thickness measured at 90° to the plane of the edge used as a striking platform and which bisects the core. For amorphous cores—which by definition cannot be oriented with respect to a striking platform—core height was taken to be the maximum linear dimension.

Breadth. For flakes, breadth is the distance between lateral margins measured at 90° to the percussion axis, midway along the length of the artefact (Andrefsky, 1998: fig. 5.9b). Where the percussion axis could not be determined, breadth was the maximum dimension of the artefact at 90° to the length, taken midway along the length of the artefact. For geometric microliths and tula adze flakes or slugs, breadth was the maximum dimension of the artefact at 90° to the length.

Thickness. Maximum distance through the artefact measured at 90° to breadth, midway along the length of the artefact (Andrefsky, 1998: fig. 5.9g). For geometric microliths, thickness was measured as the height of the backed margin.

Platform breadth. Distance across the platform between lateral margins (Andrefsky, 1998: fig. 5.5).

Platform thickness. Maximum distance across the platform (parallel to the surface) measured at 90° to platform breadth, without necessarily bisecting the ring-crack.

Platform angle. Exterior platform angle between the dorsal surface of a flake—or the face of a core—and the platform, measured to the nearest 5°.

Platform surface. Categorized as facetted (created by a series of small contiguous or overlapping flake scars); having several flake scars (created by >1 flake removals); having a single major flake scar; or cortical (all platforms which retain some cortex).

Edge angle. For flakes, edge angle is the spine-plane angle along the retouched edge to the nearest 5°. For block implements, it is the angle between major faces, along the retouched edge. This study did not routinely measure the retouch angle (producer angle) for several reasons: (*a*) the profile of the unmodified edge gives a better indication of the original steepness of an edge prior to use or modification, (*b*) this study looked at blank selection rather than discard state, and (*c*) most retouch on the Puritjarra artefacts could be considered to be either resharpening of an edge or use-damage.

Termination. The categories of flake termination used here (feather, hinge, step and plunging) follow Cotterell & Kamminga (1987).

Flake types. For flakes, three major fracture types are recognized (conchoidal, bending and bipolar) (Cotterell & Kamminga, 1987).

Cortex. This is a percentage of total surface area with cortex, recorded as an ordinal variable: no cortex; <5% cortex remaining; <50% cortex remaining; >50% cortex remaining. For flakes only the dorsal surface is included.

Flare. Parallel index for flakes (Hiscock, 1986), calculated by dividing the breadth by platform breadth. Values <1.0 indicate a flake with converging margins. Values >1.0 indicate a flake with flaring margins.

Notch width. This is maximum chord length of a notch.

Notch depth. This is the maximum depth of a notch, measured at 90° to notch width.

Appendix 2—Data sets

Several FileMaker Pro databases were created to facilitate analysis of the excavated artefacts. These are available on request from the author.

PJ/Spit Data. Basic data on the contents of each of the 336 excavation units or spits, with the depth of each excavation unit, the total weight of material excavated, the weight of each sieve fraction (6 mm and 3 mm) and of any rocks, and a breakdown of the sieve fractions by type of material (lithics, grindstones, ochre, charcoal, sandstone rubble). Counts or weights are given for each category as appropriate.

PJ/Lithics/Database-A/attribute data. Attribute data for 2622 individual artefacts. Attribute data is given for all cores (N = 131) and retouched artefacts (N = 687), and a sample of 931 unretouched flakes. All artefacts from layer II, including debitage, are entered in this database.

PJ/Lithics/Database-B/frequency data. Basic data for the entire excavated assemblage, which includes the number and weight of cores, flakes, retouched artefacts and debitage within each excavation unit. This is further broken down by raw material. This data file allows exploration of broad trends in artefact size or frequency, controlling variously for time period, raw material or artefact class using the entire assemblage.